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THE ASTROPHYSICAL JOURNAL

AN INTERNATIONAL REVIEW OF SPECTROSCOPY AND ASTRONOMICAL PHYSICS

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THE ASTROPHYSICAL JOURNAL

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THE HELIUM ARC

BY TARO SUGA

ABSTRACT

1. A direct current *arc in helium* at a pressure of about one-half of an atmosphere is described.

2. The *broadening of helium lines at the cathode* shows a striking *resemblance to the Stark effect*, and is evidently due to the influence of the neighboring atoms and ions.

3. A *continuous spectrum* of helium extending beyond the series limit for the two series $2^1S - m\,^1P$ and $2\,^3P - m\,^3D$ is observed, as was found by Paschen.

4. The previous investigation of Merton on the *analogy between the Stark effect and the broadening* of the helium lines in a condensed discharge *is extended to the red-and-yellow* region *by means of contours* obtained by a registering microphotometer.

I. INTRODUCTION

According to the recent work of O. Struve[1] and of C. T. Elvey,[2] there seems to be a close relation between the Stark effect and the widening of lines in certain stellar spectra.

Struve states in his article that much help was received from T. R. Merton's[3] work on the comparison of the broadening of helium lines, seen in a condensed discharge, with their Stark effect. It seemed to the author that an extension of Merton's work into the red and ultra-violet regions might be of some use for further studies in this direction.

We have recently experimented with the direct-current helium arc at a pressure somewhat higher than that ordinarily employed, namely, 40–50 cm of mercury.

[1] *Astrophysical Journal*, **69**, 173, 1929.

[2] *Ibid.*, p. 237.

[3] *Proceedings of the Royal Society*, A, **95**, 30, 1918.

One interesting feature presented by this kind of arc is the broadening of the helium lines at the cathode, which is so strikingly analogous to the Stark effect for helium lines that one cannot fail to recognize it at a glance.

It is true that there have already been published a number of papers showing the intimate connection of the Stark effect and the mol-electric broadening.[1] However, the element helium plays so important a rôle in astrophysics that a closer study seems worthy of an effort.

Furthermore, this work supplements that of Merton[2] in that Merton's diagram of the broadening is compared with the contours obtained by a registering microphotometer. For this purpose a condensed discharge in helium was also used as a source in addition to the helium arc.

2. EXPERIMENTAL

The arc we employed is shown in Figure 1. S is a silica bulb of about $\frac{1}{2}$-liter capacity. It was provided with three windows W_1, W_2, and W_3, all closed by silica plates, and a charcoal bulb B which was immersed in liquid air during operation.

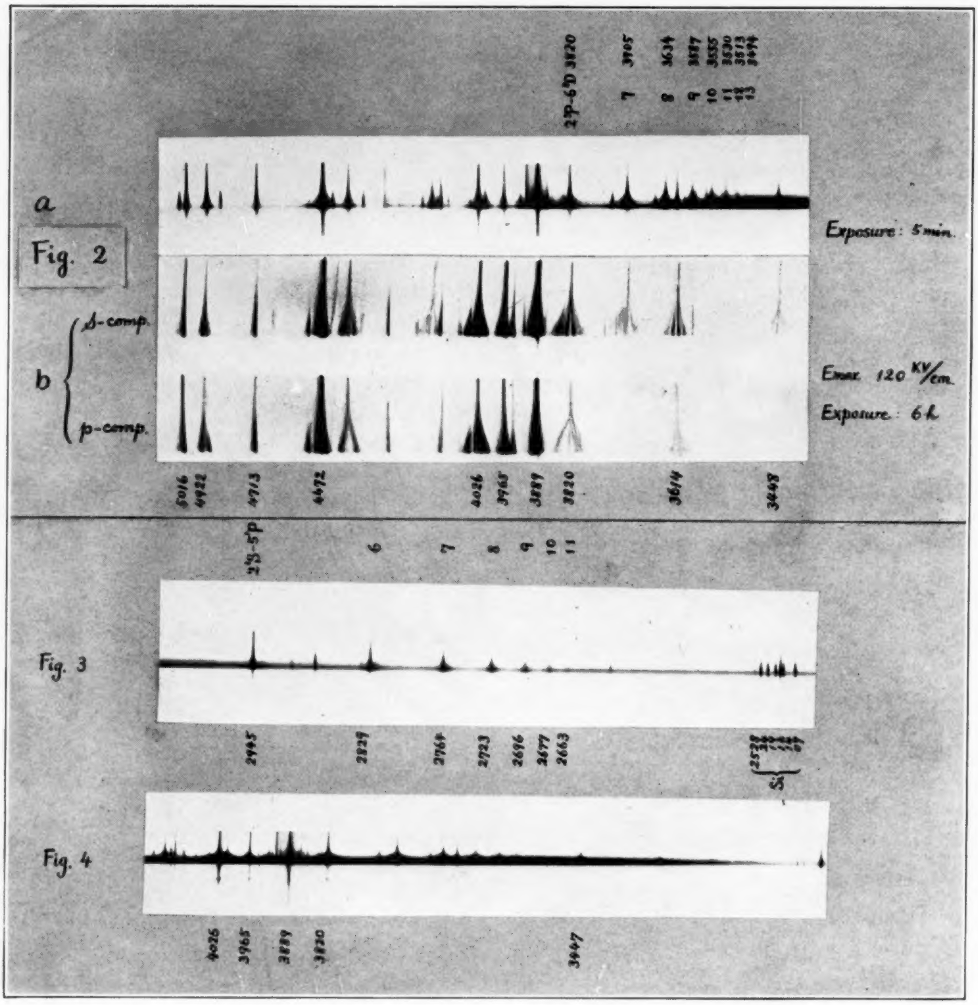
For the cathode C and the anode A we used solid tungsten cylinders about 2 cm long, having diameters of 6 and 8 mm, respectively. A and C were both screwed on to tungsten rods of 2-mm diameter and about 10-cm length. These were sealed into pyrex glass and then connected with the main silica bulb with two quartz-pyrex joints. The electrodes were covered with quartz excepting the end, and were about 1 cm apart.

For excitation, a 2.5-kw D.C. generator of 500 volts was used, the current in most cases being 3 or 4 amperes. In order to start the arc, a condensed discharge from an induction coil was first passed between A and C. The form of the arc was narrow at the cathode, widening gradually toward the anode, the intensity of the light being very strong at the narrow portion. It was this narrow bright part

[1] Stark, *Elektrische Spektralanalyse chemischer Atome*, Leipzig, 1914; Lowery, *Philosophical Magazine*, **49**, 1176, 1925; Holtsmark and Trumpy, *Zeitschrift für Physik*, **31**, 803, 1925; Nagaoka and Sugiura, *Scientific Papers of the Institute of Physical and Chemical Research* (Tokyo), **2**, 139, 1924; Takamine and Fukuda, *ibid.*, **1**, 207, 1924.

[2] *Loc. cit.*

PLATE V



THE STARK EFFECT IN HELIUM

at the cathode where the lines showed the broadening quite similar to that observed in the case of the experiments on the Stark effect.

Generally the arc burned quite steadily showing only helium lines, but occasionally it flickered and brought out the lines of impurities. In such cases it was later found that the edge of the quartz tube surrounding the electrodes had been melted.

In order to purify the helium, the gas was kept circulating through a system consisting of an all-metal diffusion pump made by Leybold, two or three charcoal bulbs cooled by liquid air, and finally a CuO_2 vessel heated at 500° C. A Töpler pump and an open-end mercury manometer served for filling the quartz bulb with pure helium up to the pressure of 50 or 60 cm.

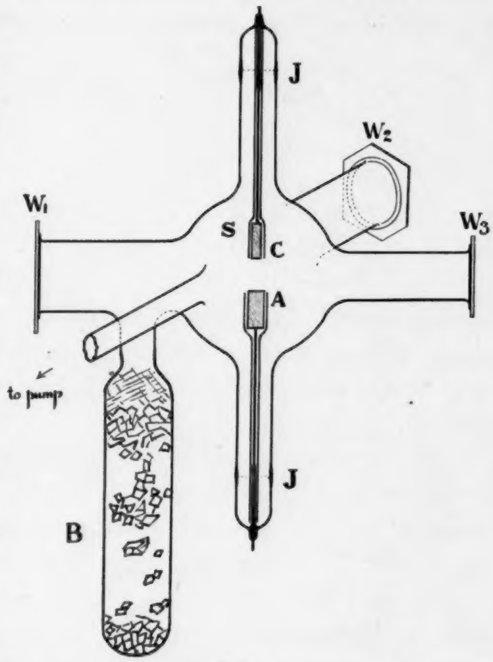


FIG. 1

The optical instruments used were a quartz spectrograph of size E2, a spectrograph of uviol glass, and a wave-length spectrometer with camera attachment, all made by Hilger. For photography in the ordinary region we used Ilford Special Rapid or Ilford Process plates, and for the near infrared portion, "Extreme-Red Sensitive" plates by the Eastman Kodak Company, or Ilford special rapid panchromatic plates. The exposures ranged from a few seconds up to 30 minutes.

3. RESULTS

The analogy between the broadening and the Stark effect is most strikingly shown in Plate V, Figure 2. Here (*a*) is the photograph of the helium arc taken by a Hilger uviol spectrograph, while (*c*) is

the picture of the Stark effect taken with the Hilger quartz spectrograph E6. The latter was taken by Mr. Y. Fujioka[1] during his studies on the Stark effect in helium employing Lo Surdo's method, and was kindly placed at the author's disposal.

Besides the unmistakable correspondence in the manner of the broadening, we can at once recognize the appearance of the following "forbidden" lines in the spectrogram of the helium arc:

λ in A	Series
4516	$2\,{}^3P-4\,{}^3P$
4381	$2\,{}^1P-5\,{}^1P$
4046	$2\,{}^3P-5\,{}^3P$
3974	$2\,{}^1P-4\,{}^1D$
3829	$2\,{}^3P-6\,{}^3P$
3711	$2\,{}^3P-7\,{}^3P$
3618	$2\,{}^1S-5\,{}^1D$

The amount of broadening is smaller in the arc than in the particular picture of the Stark effect here taken, the maximum electric field at the surface of the cathode being about 120 kv/cm for the latter.

On the other hand, higher members of the $2\,{}^3P-m\,{}^3D$ series come out with great intensity up to the thirteenth member. The same feature for $2\,{}^1S-m\,{}^1P$ series is shown in Plate V, Figure 3, taken with the Hilger quartz spectrograph E2.

For each of the two series $2\,{}^3P-m\,{}^3D$ and $2\,{}^1S-m\,{}^1P$, we notice that the higher members merge into a continuous spectrum which extends far out beyond the series limit. In Plate V, Figure 4, we reproduce a photograph showing the continuous spectrum for the series $2\,{}^3P-m\,{}^3D$.

This corresponds exactly with what Paschen[2] published in 1926 in his work entitled "Serienenden und molekulare Felder"; and these data were later used by Robertson and Dewey[3] in their work on the Stark effect and series limit.

In the experiment of Paschen, the pressure in the discharge tube was very low compared with the present case so that the resulting

[1] *Scientific Papers of the Institute of Physical and Chemical Research* (Tokyo), **7**, 263, 1927.

[2] *Sitzungsberichte der Preussischen Akademie der Wissenschaften*, **16**, 135, 1926.

[3] *Physical Review*, **31**, 973, 1928.

PLATE VI

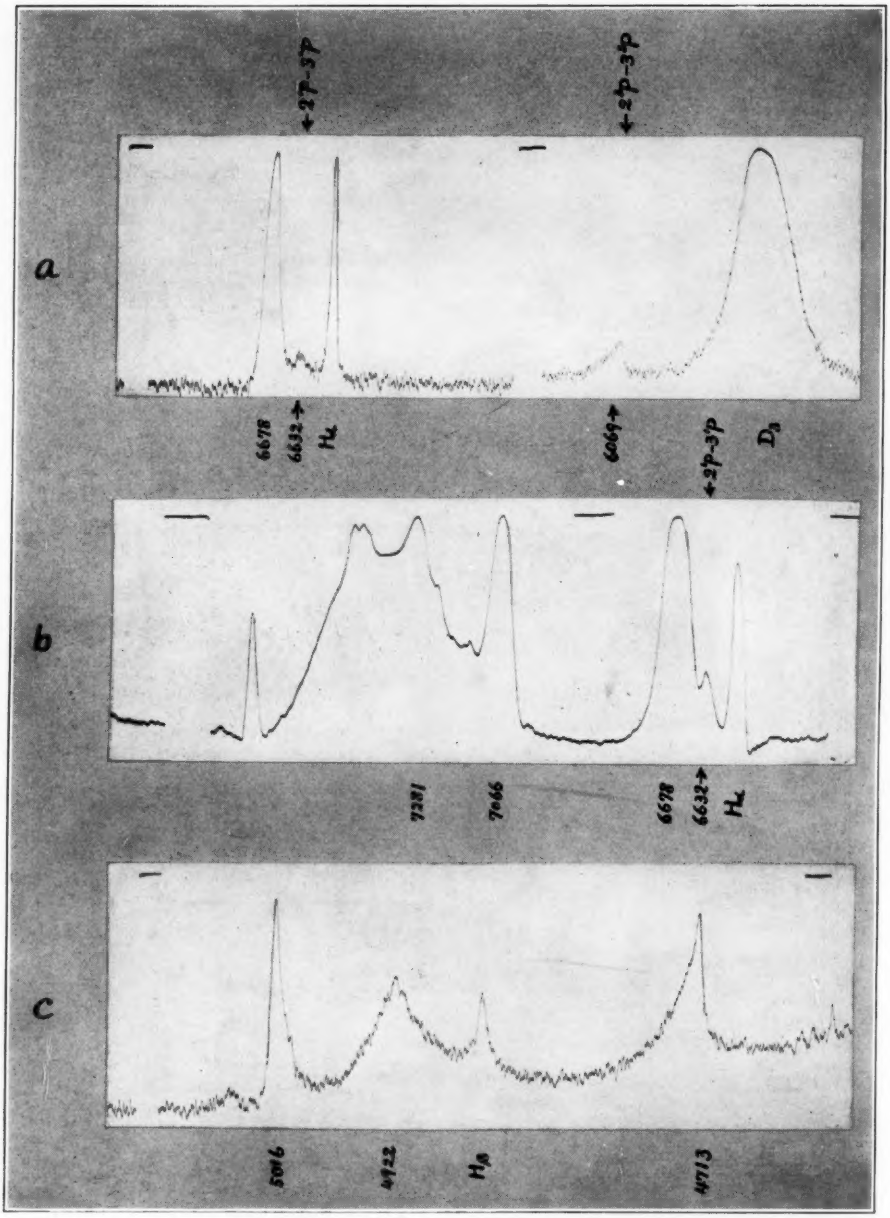


FIG. 5.—DENSITY CURVES OF HELIUM LINES BROADENED BY STARK EFFECT

spectrogram naturally showed quite different features. For instance, in the cathode glow of a cylindrical electrode, Paschen obtained the lines of $2\,{}^3P - m\,{}^3D$ and $2\,{}^1P - m\,{}^1D$ series clearly decomposed into Stark components, whereas in our case these lines are merely broadened on account of the heterogeneous field.

On the other hand, the reduced pressure in the case of Paschen brought out the helium band spectrum, which is seen superimposed on the continuous spectrum. For the purpose of measuring the intensity of the continuous spectra of helium, as was attempted by Robertson and Dewey,[1] it would seem that the helium arc here described would serve better, especially as regards its strong intensity which enables us to get a spectrogram with only a few seconds' exposure.

Turning to the red-and-yellow part, we notice that the amount of maximum electric field in the case of the arc is not large enough to show the analogy between the Stark effect and broadening. Consequently, for this part we find it more convenient to employ a heavily condensed discharge in helium instead of the helium arc.

The method of excitation here used has already been described in section 2. The optical instruments employed were either Hilger's wave-length spectrograph with a camera or a plane-grating spectrograph with the collimator and objective lenses of 6-cm aperture and 60-cm focal length.

The contours obtained by a registering microphotometer after Moll, constructed by Kipp and Zonen, are shown in Figures 5*a*, 5*b*, and 5*c*, Plate VI.

Figure 5*a* shows the unsymmetrical broadening of the D_3 line ($2\,{}^3P - 3\,{}^3D$), as was already observed by Takamine[2] in 1926. This is in agreement with the fact that the Stark effect for this line was found to be a shift in the same direction.[3] Further, as marked by an arrow, the appearance of the forbidden line λ 6069 ($2\,{}^3P - 3\,{}^3P$) is clearly seen in the curve.

[1] *Loc. cit.*

[2] *Scientific Papers of the Institute of Physical and Chemical Research* (Tokyo), **5**, 55, 1926.

[3] Takamine and Kokubu, *Memoirs of the College of Science, Kyoto*, **3**, 81, 1918; Ishida and Kamishima, *Scientific Papers of the Institute of Physical and Chemical Research* (Tokyo), **9**, 117, 1928.

Figure 5*b* shows the broadening of λ 6678 ($2\,^3P-3\,^3D$) to the red and also the appearance of the component 6632 ($2\,^1P-3\,^1P$) on the violet side. This is in good accord with results for the Stark effect obtained in 1916 by Takamine and Kokubu,[1] who noted the red shift of the main line in an electric field. In 1927 Ishida and Kamishima[2] not only confirmed this point, but found the appearance of the forbidden line 6632 under much more improved experimental conditions.

Figure 5*c* shows the contour of lines in the region from λ 5016 to λ 4713. It will be seen that the essential features are entirely analogous to those given by Merton.[3]

In conclusion the writer wishes to express his sincere thanks to Professor T. Takamine for his kind guidance and for the deep interest he has taken in the present experiments.

TOKYO
August 1929

[1] *Loc. cit.* [2] *Loc. cit.* [3] *Loc. cit.*

THE RADIAL VELOCITIES OF 741 STARS[1]

By W. S. ADAMS, A. H. JOY, R. F. SANFORD, and G. STRÖMBERG

ABSTRACT

This catalogue contains the *radial velocities* and *spectral types* of 741 stars observed at Mount Wilson with spectrographs of one-prism dispersion. The visual magnitudes range from 3.0 to 10.8, many faint dwarf stars being included.

The following *corrections* have been applied to the directly measured values: F, +0.5 km/sec.; G, 0.0; K, −0.9; M, −0.8.

Comparisons are made with 142 stars observed in common with the Lick Observatory, and 96 stars observed at the Dominion Astrophysical Observatory.

The *asymmetry* of stellar motions is shown in a striking way by the numerous stars of high radial velocity.

This catalogue of radial velocities contains the results for 741 stars observed at Mount Wilson during recent years with the spectrographs at the Cassegrain focus of the 60-inch and 100-inch reflectors. In all cases a dispersion of one prism has been used, but the prism employed in the spectrograph of the 60-inch telescope is of somewhat denser glass than the other and affords a larger scale. Cameras of 18-inch focal length are used in both instruments, supplemented in the case of the spectrograph of the 100-inch telescope by a 10-inch camera for observations on the fainter stars. The linear scale of the spectrograms ranges from 37 A to the millimeter at $H\gamma$ for the spectrograph on the 60-inch telescope with the 18-inch camera, to 76 A for the spectrograph on the 100-inch with the 10-inch camera.

Table I gives the results found for the radial velocities. The arrangement is the same as that in *Mt. Wilson Contribution*, No. 258.[2] The list contains stars ranging in visual magnitude from 3.0 to 10.8. The photographic magnitudes of many of the fainter stars reach 11.0. The brighter stars were observed for the double purpose of providing spectra suitable for determinations of absolute magnitude and parallax and of furnishing a comparison with the values for such stars measured at the Lick Observatory. The number of stars

[1] *Contributions from the Mount Wilson Observatory, Carnegie Institution of Washington*, No. 387.

[2] *Astrophysical Journal*, **57**, 149, 1923.

TABLE I

RADIAL VELOCITIES OF 741 STARS

H.D.	STAR		α 1900	δ 1900	m	SP.	μ	No.	v	P.E.	OTHER DETERMINATIONS v	OTHER DETERMINATIONS Auth.
									km/sec.	km/sec.	km/sec.	
....	Cin.	2S	0h 0m.4	+45° 15′	8.5	M0	0″.858	4	+ 1	±1		
87	Boss	2	0 0.6	+12 50	5.7	G5	.035	3	− 2.1	1.4	+ 2.6	V
693		22	0 6.2	−16 1	5.0	F4s	.280	4	+ 13.7	1.5	+15.0	L
787		25	0 7.1	−18 30	5.5	K5	.040	3	− 8.2	3.1	− 8.0	L
1014		30	0 9.4	− 8 20	5.4	M4	.060	2	− 6.0	0.5	− 2.4	L
1228		40	0 11.5	+ 1 18	7.3	M5	.022	4	− 7.9	1.6		
1317		45Br	0 12.3	+ 8 19	6.6	G1	.120	3	+ 32.0	1.2	+36.6	V
1671		57	0 15.9	+37 25	5.2	F2s	.078	3	+ 8.9	1.4	+ 9.5	L
1779	Cin.	35	0 17.0	−27 16	9.0	G1	.440	3	− 5	2		
1879	Boss	64	0 18.0	−16 30	6.6	M3	.041	3	− 22.3	2.3		
....	Cin.	41	0 19.3	−27 35	8.0	K4	.669	3	+ 6	1		
2806	Boss	98	0 26.4	+15 28	7.1	G9	.049	3	− 5.7	1.0		
2910		104	0 27.3	+19 45	5.5	K0	.138	3	− 11.5	1.1		
3125		112	0 29.4	− 5 6	7.0	G1	.082	3	+ 9.1	3.0		
3266A	βG.C.	322A	0 30.6	+29 27	7.9	G4	.449	5	− 49.5	1.5		
3266B		322B	0 30.6	+29 27	8.7	G6	.449	3	− 59	1		
3821		368Br	0 35.7	− 7 46	7.0	G3	.022	3	+ 4.7	0.8		
....	Cin.	90	0 38.2	+33 18	8.5	K6	.427	3	− 33	1		
4307	Boss	157	0 40.5	−13 25	6.1	F9	.200	3	− 12.8	0.6		
4568		167	0 42.6	+20 23	6.6	F8	.162	3	+ 3.4	1.4	− 1.0	V
4730		177	0 44.4	−14 6	5.8	K5	.135	3	+ 3.1	1.6		
5351	Cin.	122	0 50.4	+68 31	9.4	K6	.739	3	− 46	3		
6314	Boss	231	0 59.0	+39 27	6.7	A3n	.088	3	+ 5	1	+12.4	V
6734		251	1 2.9	+ 1 28	6.7	G5	.446	3	− 94.9	0.3		
6920		262	1 4.6	+41 33	5.7	F8	0.145	4	− 8.4	±0.9	−13.1	V

									km/sec.	km/sec.	km/sec.	
7218	Boss	275	1h 7m4	+ 1° 57′	6.8	F5	0″.208	4	+ 3.2	±1.4		
7672		290	1 11.5	− 3 2	5.5	G4	.126	4	− 19.8	2.3		
7727		291	1 11.9	− 2 48	6.8	G0	.296	3	+ 8.0	1.9		
8126		303	1 15.6	+28 13	5.6	K5	.050	3	− 35.5	1.0		
8334		306	1 17.5	+ 1 12	6.5	M0	.069	4	− 15.7	2.3		
8491		310	1 18.9	+67 36	5.0	G9	.086	3	− 7.8	0.3	−12.0	L
8627	βG.C.	749Br	1 20.0	− 6 28	6.8	F0	......	3	+ 15.5	0.9		
8705	Boss	317	1 20.7	−15 7	5.2	K3	.043	3	− 20.8	1.2	−21.0	L
......	B.D. +59°	251	1 20.9	+59 46	8.5	B3	......	3	− 42	3		
8763	Boss	319	1 21.3	+18 43	5.6	G9	.076	4	− 41.2	1.2		
8779		320	1 21.3	− 0 55	6.5	G9	.049	3	− 6.6	1.3		
9352–3	B.D. +57°	320	1 27.0	+57 49	6.0	K0p	......	3	− 1.0	1.4		
9640	Boss	342	1 29.4	+17 57	6.0	M2	.088	4	− 26.4	1.7		
9670		344	1 29.7	+ 0 26	7.0	F8	.323	3	− 18.1	2.1		
9847	Cin.	216	1 31.0	−18 2	7.1	G1	.353	5	+ 7.5	1.4		
10113	Boss	361	1 33.9	+16 7	6.9	G5	.031	3	+ 4.5	1.4		
10164		367	1 34.3	+15 54	6.1	K1	.073	3	+ 18.7	1.5	+17.1	V
12292		455	1 55.5	− 9 0	5.7	M5	.086	3	+ 6.8	1.9		
12800		475	2 0.5	+71 5	6.7	F8	.389	3	+ 0.8	1.1	− 2.1	V
13137		481	2 3.4	+53 22	6.4	G5	.060	5	+ 10.5	0.8		
13174		483	2 3.7	+25 28	5.1	A7	.086	3	− 6	1	+ 3::	L
13325		491	2 5.1	+19 2	5.9	M3	.092	3	+ 60.3	2.6		
13452	βG.C.	1136Br	2 6.4	+53 46	8.1	A0	.010	4	+ 9	4		
13421	Boss	495	2 6.1	+ 8 6	5.7	F9	.174	3	− 16.7	1.3	−19.2	V
13468		496	2 6.5	− 2 18	6.0	G8	.026	3	+ 32.1	0.4		
13596		502	2 7.6	+14 49	6.0	M1	.100	4	+ 26.2	1.7		
13612		503	2 7.7	− 2 52	8.7	G3	.374	3	− 5	1		
13872		509	2 10.0	+24 35	5.6	F4	.120	3	− 44.3	0.4		
14411	B.D. − 3°	355	2 14.5	− 3 25	9.1	K5	.010	4	+ 39	1		
15089	Boss	550A	2 20.8	+66 57	4.6	cA4	0.015	2	+ 2	±1	+ 3.3	L

TABLE I—*Continued*

H.D.	Star		α 1900	δ 1900	m	Sp.	μ	No.	v	P.E.	Other Determinations v	Other Determinations Auth.
									km/sec.	km/sec.	km/sec.	
....	Boss	550C	2h 20m.8	+66° 57′	8.1	G4	0″.03	3	+ 10	±1		
15176		555	2 21.5	+31 21	5.8	G9	.046	4	− 38.0	1.7	−40.3	V
15596		568	2 25.4	+17 16	6.4	G5	.103	3	−116.0	2.8		
15652		570	2 26.0	−22 59	6.4	M2	.044	3	− 18.9	1.0		
16082–3		585	2 29.9	+51 31	7.3	G1	.014	3	− 16.0	0.8		
16141		586	2 30.3	− 3 59	6.8	G1	.452	3	− 53.8	2.2		
16396	βG.C.	1346Br	2 32.9	+32 59	7.0	K2	......	3	− 3.8	1.4		
16480		1353Br	2 33.5	+14 25	7.3	K0	......	4	+ 0.8	1.6		
16647	Boss	607	2 35.0	+ 5 41	6.2	F2s	.050	5	+ 18.5	1.1	+16.7	V
16735	βG.C.	1376Br	2 35.9	+53 6	6.0	G8	.079	4	− 11.0	1.5		
17206	Boss	631	2 40.4	−19 0	4.6	F5s	.327	6	+ 23.6	1.1	+26.2	L
17245–6	B.D. +43°	576	2 41.0	+43 50	6.7	F0s	......	3	− 13.7	0.5		
17459	Boss	635	2 42.9	+17 52	6.0	G8	.051	3	+ 47.8	1.4	+46.5	V
17660	Cin.	365	2 45.0	+15 19	9.2	K6	.510	5	− 26	2		
17785	βG.C.	1457S	2 46.1	+72 29	7.7	G0	.082	3	− 3.0	1.3		
18200	Cin.	379	2 50.3	+52 5	8.0	G6	.49	3	+ 32.8	1.8		
18449	Boss	670	2 52.9	+34 47	5.0	K2	.063	3	− 36.1	0.8	−36.0	L
18537		678	2 53.7	+51 57	5.4	B5	.043	3	− 2	3	− 3::	L
18633		682	2 54.6	− 2 52	5.5	B9	.017	5	+ 17	3	+24	L
18692		684	2 55.2	−25 40	5.6	A9n	.204	3	+ 21	1		
18803		689	2 56.5	+26 13	6.7	G5	.295	3	+ 15.6	1.2	+ 8.0	V
18907		693	2 57.3	−28 28	5.9	G5	.493	3	+ 31.7	2.5		
18975	βG.C.	1550Br	2 58.0	− 2 29	7.7	F7	......	3	+ 34.8	2.2		
20418	Boss	744	3 12.0	+49 44	5.1	B3	.041	6	+ 1	5	− 2::	L
21017		775	3 18.4	+24 22	5.7	K3	0.059	4	+ 13.1	±1.4	+11.7	V

										km/sec.	km/sec.	km/sec.	
21278	Boss	780	3h 20m.9	+48° 43′	4.9	B5	0″.032	6	+ 4	±2	+11	L
21531	Cin.	456	3 23.3	−20 10	8.2	Mo	.603	4	+ 31.0	1.5		
21903	βG.C.	1747Br	3 26.8	+59 43	6.5	F2s	....	3	+ 20.5	0.3		
22468Ft	Boss	823Ft	3 31.7	+ 0 16	8.2	K6	.151	5	− 15	2		
23107	βG.C.	1827Br	3 37.4	+38 4	7.4	K4	.03	3	+ 15.6	1.0		
23108		1827Ft	3 37.4	+38 4	8.7	A5n	.03	3	+ 13	2		
23189	Cin.	499	3 38.2	+68 21	9.1	M1	.30	3	− 5	2		
23413	Boss	859	3 39.8	− 0 37	5.8	K5	.054	3	+ 69.3	2.0		
23480		865	3 40.4	+23 38	4.2	B5	.059	2	+ 13	1	+ 1::	L
23614		868	3 41.4	−12 25	4.6	M2	.069	3	+ 42.7	1.0	+45.7	L
23630		869	3 41.5	+23 48	3.0	B5p	.052	3	+ 14	6	+ 5	L
23850		877	3 43.2	+23 45	3.8	B8	.053	2	+ 6	5	+ 3:	L
23862		879	3 43.2	+23 50	5.2	B8p	.053	2	+ 14	1	+ 3:	L
23940		881	3 43.9	−30 28	5.6	G3	.243	3	+ 53.3	0.6		
24131		886	3 45.5	+34 3	5.7	B3	.011	4	+ 18	2		
24388		893	3 47.8	− 5 40	5.5	B8	.012	3	+ 15	4	+18:	L
24640		904	3 50.0	+34 47	5.5	B3	.020	3	+ 13	2	+25::	L
24834		912	3 51.8	−13 53	6.7	M2	.010	3	+ 38.0	1.4		
25570		935	3 58.5	+ 7 55	5.5	F2s	.159	3	+ 31.5	1.0	+36.0	L
25665	Cin.	546	3 59.2	+69 17	8.1	K2	.308	3	− 11	2		
26018		553	4 2.1	+76 2	8.8	Ko	.25	6	+ 10	1		
26367	Boss	958	4 5.1	+85 17	6.7	F8	.038	6	− 47.0	1.4		
27176		991	4 12.5	+21 20	5.6	A8n	.112	5	+ 33	2		
....	B.D. +15°	609	4 12.6	+15 51	9.0	K4	....	5	+ 41	2		
27245	Boss	993	4 13.1	+60 30	5.7	Mo	.122	3	+ 28.2	1.2		
27757	Cin.	580	4 17.8	+77 24	7.8	F9	.237	3	+ 38.0	0.1		
27991	Boss	1031	4 19.9	+15 43	6.4	F5s	.114	3	+ 38.7	0.9		
28034	B.D. +15°	624	4 20.4	+15 17	7.4	F7	.115	5	+ 41.1	2.0		
28226	Boss	1040	4 22.1	+21 24	5.7	A8n	0.118	5	+ 35	3	+35.7	V
....	B.D. +14°	699	4 22.1	+14 8	9.3	K3	....	3	+ 46	±2		

TABLE I—*Continued*

H.D.	Star	α 1900	δ 1900	m	Sp.	μ	No.	v	P.E.	Other Determinations v	Other Determinations Auth.
								km/sec.	km/sec.	km/sec.	
28424	B.D. +13° 688	4h23m9	+13°41′	7.8	G9	....	3	+ 94.4	±2.0		
28595	Boss 1057	4 25.4	+14 53	6.6	M3	0″.074	3	+ 38.0	0.2		
28704	1061	4 26.4	+42 51	6.1	A9n	.007	6	− 24	3		
28749	1063	4 26.8	− 0 16	5.0	K4	.003	3	+ 18.2	0.8	+16.2	L
....	B.D. +55° 900	4 27.9	+55 13	8.6	K4	.64	3	+ 50	2		
....	+14° 721	4 28.3	+14 57	8.5	K1	....	3	+ 37	1		
....	+14° 722	4 28.6	+14 46	8.7	K4	....	3	− 24	1		
29009	Boss 1070	4 29.0	− 6 57	5.7	B9	.012	6	+ 2	2		
29064	1071	4 29.4	− 8 26	5.4	M3	.035	3	− 10.3	1.3	−11.6	L
29065	1072	4 29.4	− 9 11	5.5	K5	.119	3	− 25.0	2.3	−27.4	L
29235	βG.C. 2274Br	4 31.1	+41 57	7.2	K2	.026	3	+ 16.7	0.9		
29364	2284N	4 32.4	+26 45	6.5	F2s	....	4	+ 3.9	2.8		
29775	Boss 1105	4 36.1	−19 52	4.5	M3	.094	3	− 32.3	2.1	−33.5	L
30020	1112	4 38.8	− 8 59	6.8	F1s	.044	3	+ 40.0	1.3		
30454	1129	4 42.8	+31 16	5.8	K1	.115	3	+ 22.0	0.4	+22.7	V
30504	1133	4 43.2	+37 19	5.1	K3	.046	2	− 22.7	0.2	−24.3	L
30834	1148	4 45.9	+36 32	5.0	K2	.026	2	− 15.9	0.2	−16.7	L
31865	βG.C. 2451S	4 54.2	+62 57	8.6	G4	.336	3	− 24	1		
32070	Cin. 646	4 55.5	+24 30	8.5	G2	.322	3	+ 29	1		
33664	Boss 1237	5 6.7	−11 58	5.9	M6	.051	3	+ 45.8	0.9		
33725	Cin. 674	5 7.1	− 9 13	8.0	K0	.57	4	+ 5.4	1.5		
....	Comp. α Aurigae	5 10.0	+45 44	9.8	M2	.437	3	+ 36	5		
....	B.D. +41° 1154	5 13.0	+41 8	8.7	K0	....	3	+ 39	2		
35186	Boss 1292	5 17.9	+37 18	5.2	K5	.027	3	− 16.8	2.4	−20.0	L
35410	1300	5 19.4	− 0 59	5.2	G6	0.125	4	+ 22.3	±0.8	+20.0	L

									km/sec.	km/sec.	km/sec.	
35620	Boss	1311	5h 21m.0	+34° 23′	5.3	K4	0″.056	3	+ 30.6	±2.0	+31.0	L
35783	Cin.	693	5 22.1	+78 18	7.7	F3s	.258	3	+ 18.7	1.4		
36167	Boss	1327	5 24.6	− 1 10	5.0	Mo	.028	4	+ 5.9	1.7	+ 7.9	L
36443	Cin.	706	5 26.6	+ 0 2	8.4	G5	.507	3	− 9	2		
....	βG.C.	2835Ft	5 30.5	+21 56	7.8	F7	.028	3	+ 25.2	1.4		
37269	Boss	1378	5 32.2	+30 26	5.5	A9n	.016	3	+ 4	2	+ 0.8	L, V
37603	βG.C.	2886Br	5 34.6	+15 18	6.7	Fon	....	4	+ 21.1	1.2		
37984	Boss	1407	5 37.3	+ 1 26	5.2	K1	.055	3	+ 85.2	1.7	+89.2	L
38014	Cin.	724	5 37.5	+ 2 39	8.8	K1	.54	3	+ 55	2		
38584	Boss	1425	5 41.8	+24 39	7.2	K4	.028	3	+ 15.6	0.4		
38604		1426	5 41.9	+39 30	6.9	G1	.024	3	+ 19.5	1.8		
38998	B.D. +27°	887	5 44.5	+27 39	7.7	M5	....	3	+ 27	1		
39019	Boss	1445	5 44.8	+14 17	5.7	Ko	.035	3	+ 45.8	0.6	+44.7	V
39400		1458	5 47.2	+ 1 50	5.0	K2	.011	3	+ 10.4	0.9	+10.3	L
39425		1459	5 47.4	−35 48	3.2	Ko	.397	3	+ 94.6	2.5	+89.1	L
39853		1470	5 50.1	−11 48	5.8	K4	.062	3	+ 87.0	1.3		
40002	B.D. +26°	1011	5 51.1	+26 51	8.0	K2	....	3	− 33	3		
40239	Boss	1479	5 52.5	+45 56	4.6	M3	.011	3	0.0	0.5	+ 0.9	L
40369–70		1485	5 53.2	+12 48	5.8	G5	.035	3	+ 11.0	1.7		
40959	βG.C.	3113Br	5 57.4	+27 39	8.8	G4	.42	3	− 2	1		
42042	Boss	1531	6 3.3	−19 9	5.5	M2	.063	6	+ 29.1	1.9		
42250	Cin.	769	6 4.5	+70 49	7.6	G6	.45	4	+ 25.6	2.4		
42618		772	6 6.6	+ 6 49	7.1	G4	.306	3	− 54.4	0.7		
43232	Boss	1570	6 10.0	− 6 15	4.1	K1	.021	3	− 3.4	1.0	− 5.2	L
....	Cin.	783	6 10.5	+25 15	9.1	K5	.48	3	+ 44	2		
44213	βG.C.	3319Br	6 15.5	+ 5 47	8.1	M4	....	3	+ 16	1		
44214		3319Ft	6 15.5	+ 5 47	9.8	A6n	....	3	+ 42	2		
44252	B.D. +22°	1294	6 15.6	+22 57	8.1	F4	....	4	+ 37.5	2.5		
44770	Boss	1611Ft	6 18.5	+ 4 39	6.5	F6s	.012	3	+ 16.3	0.4		
45018		1616	6 19.9	−25 31	5.7	M1	0.031	3	+ 33.2	±1.2		

TABLE I—*Continued*

H.D.	Star		α 1900	δ 1900	m	Sp.	μ	No.	v	P.E.	Other Determinations v	Other Determinations Auth.
									km/sec.	km/sec.	km/sec.	
45416	Boss	1626	6h 22m.1	+ 0° 22′	5.3	G8	0″.011	3	+ 29.8	±2.3	+33.3	L, V
....	Cin.	803	6 22.9	+27 5	8.7	K5	.50	3	− 47	1		
45951	βG.C.	3422Br	6 25.4	+17 0	6.2	K1	.089	4	+ 26.5	1.0		
46136	Boss	1650	6 26.5	+17 51	7.8	F6	.042	3	+ 0.2	0.7	− 0.5	V
46374		1663	6 27.9	+14 14	5.6	K1	.097	3	− 12.5	1.4		
....	B.D.	+17° 1320	6 31.4	+17 38	9.5	M1	.88	3	− 59	2		
47127	Cin.	814	6 32.0	+12 16	7.6	G5	.292	6	+ 52.4	1.9		
47914	Boss	1707	6 35.8	+44 37	5.2	K5	.055	3	− 72.1	0.3	−75.8	L
48217		1715	6 37.2	− 9 4	5.3	Mo	.037	2	+ 1.6	2.0	+ 0.3	L
48250		1716	6 37.4	+59 33	4.9	A3n	.015	4	− 6	3	+ 7	L
49520		1748	6 43.7	+41 54	5.0	K3	.136	3	+ 60.8	1.3	+60.6	L
49618–9		1753	6 44.3	+59 34	5.4	Go	.047	3	+ 11.7	1.4	+13.1	L, V
49968		1760	6 45.9	+23 43	5.8	K5	.043	3	+ 39.7	2.0		
50635		1778Ft	6 49.0	+13 18	7.7	G5	.112	3	+ 25.4	1.8		
50692		1780	6 49.2	+25 30	5.8	Go	.042	3	− 11.8	0.7	....	
50806		1784	6 49.6	−28 24	6.0	G3	.524	4	+ 71.7	1.1		
51067	Cin.	840	6 50.8	+75 22	6.8	F8s	.265	3	+ 22.9	0.7		
52005	Boss	1803	6 54.5	+16 13	5.9	cK4	.018	3	+ 21.8	0.6	+21.4	V
52666		1808	6 57.0	− 5 35	5.4	M2	.009	3	− 0.8	2.5	+ 1.6	L
54046	Cin.	855	7 2.3	+15 41	7.5	F9	.231	4	− 12.7	2.3		
54100		856	7 2.5	+15 41	7.4	F8	.213	3	− 11.1	2.1		
55458		867	7 7.8	+25 11	8.4	K1	.451	3	− 51.8	0.9		
55751	Boss	1865	7 9.1	+ 3 17	5.6	K1	.030	3	+ 36.7	0.8		
56160		1878	7 10.8	−26 52	5.8	K5	.047	3	+ 14.2	2.1		
56618		1889	7 12.6	−27 42	4.8	M3	0.045	3	+ 43.4	±1.1	+40.6	L

									km/sec.	km/sec.	km/sec.	
....	B.D.	+33°1505	7h13m0	+33° 2′	9.3	M1	0″.57	3	− 61	±2		
57615..........	Boss	1918	7 17.0	−25 42	6.1	M5	.031	3	+ 23.1	0.9		
58461..........		1938	7 20.6	−13 33	5.8	A8n	.204	3	+ 7	2		
....	βG.C.	4062Br	7 22.3	+50 11	8.2	G2	....	3	− 77	1		
....		4062Ft	7 22.3	+50 11	8.7	G2	....	3	− 2	1		
58945..........		4065	7 22.7	+50 12	8.0	F4n	....	4	+ 14.7	2.9		
59604–5........	B.D.	+ 8°1791	7 25.6	+ 8 46	7.2	F1s	....	4	+ 23.8	1.6		
60081..........	Boss	1975	7 27.7	+15 51	6.7	G9	.008	3	+ 55.8	1.0		
60437..........		1986	7 29.3	+46 24	5.8	M1	.047	3	+ 28.9	0.2		
....	B.D.	+37°1748	7 31.6	+36 57	9.5	K5	0.87	3	− 8	1		
61421..........	Boss	2008	7 34.1	+ 5 29	0.5	F4	1.242	7	− 1.7	0.6	− 3	L
62285..........		2028	7 38.0	+26 1	5.4	M0	0.034	3	+ 3.7	0.4	+ 1.8	L, V
....	B.D.	+54°1175	7 40.8	+53 55	8.6	K6	.56	3	+ 2	2		
62902..........	Boss	2050	7 41.1	− 6 32	5.7	K5	.110	5	− 32.8	1.3		
63332..........		2057	7 43.2	+54 23	6.0	F6	.052	4	− 2.4	1.5		
63336..........		2058Br	7 43.3	−11 57	5.5	F5	.125	5	+ 26.0	1.4		
63700..........		2065	7 45.1	−24 37	3.5	G0p	.007	3	− 3.8	1.7	+ 3.9	L
63752..........		2068	7 45.4	− 8 56	5.8	K3	.014	3	− 7.4	1.7		
67458..........	Cin.	961	8 2.9	−29 6	6.9	G0	.546	3	− 19.2	1.8		
67501..........	βG.C.	4452Br	8 3.2	+32 31	6.7	F6	....	3	+ 11.4	0.4		
68146..........	Boss	2163	8 6.0	−13 30	5.6	F8	.235	3	+ 37.7	0.4		
68638..........	Cin.	971	8 8.1	+57 24	7.8	G5	.394	3	+ 17.7	1.3		
68744..........		973	8 8.7	+73 39	8.6	G0	.271	3	+ 52	1		
68788..........		974	8 8.8	+73 44	8.6	K1	.559	3	− 4	2		
68951..........	Boss	2186	8 9.7	+72 43	6.2	M0	.027	3	+ 11.2	0.6		
....	B.D.	+33°1694	8 18.9	+32 58	9.2	K6	.69	4	− 78	1		
71093..........	Boss	2232	8 20.4	+28 13	5.8	K2	.134	4	+ 23.8	1.4	+24.3	V
71153..........		2239	8 20.7	+24 52	7.6	F5	.093	3	+ 18.3	0.5	+17.7	V
71377..........		2248	8 22.0	−12 12	5.7	K2	.095	3	+ 65.0	2.7		
....	B.D.	+46°1405	8 22.5	+46 15	9.4	K6	0.571	4	− 23	±1		

TABLE I—*Continued*

H.D.	Star	α 1900	δ 1900	m	Sp.	μ	No.	v	P.E.	Other Determinations v	Other Determinations Auth.
								km/sec.	km/sec.	km/sec.	
71881	Cin. 996	8h 24m.6	+50°58′	7.4	G0	0″.376	4	+ 16.7	±0.9		
71952	Boss 2260	8 25.1	+53 27	6.5	G8	.088	3	+ 44.1	1.7		
72094	2265	8 25.9	+18 26	5.6	M1	.087	3	+ 44.2	1.5		
72292	2271	8 26.9	+20 47	5.5	K5	.065	3	+ 25.3	0.4	+22.1	V
72626	βG.C. 4668m	8 28.8	−24 16	6.2	A5n	....	4	− 8	2		
73668	Cin. 1016	8 34.4	+ 6 8	7.8	G4	.326	3	− 22.2	1.5		
73840	Boss 2315	8 35.3	−12 7	5.2	K5	.087	2	− 12.5	0.5	−11.4	L
74000	B.D. −15°2546	8 36.2	−15 59	9.4	A9	.558	3	+200	5		
74137	Boss 2321	8 37.1	−15 35	5.0	G8	.099	4	− 3.4	2.1	− 1.8	L
75332	2364	8 44.3	+33 40	6.2	F7	.113	3	+ 4.6	1.2	+ 4.4	V
75700	B.D. +12°1927	8 46.3	+12 16	7.8	K0	....	3	− 4.9	1.9		
76219	Boss 2391	8 49.7	+28 19	5.2	G5	.041	3	+ 17.3	1.4	+17.2	L
....	B.D. +21°1947	8 52.1	+20 50	9.0	F3	.73	4	+ 36	1		
76644	Boss 2404	8 52.4	+48 26	3.1	A2n	.502	5	+ 9	3	+13	L
77175	βG.C. 4890N	8 55.8	+15 41	8.7	K6	.328	3	− 13	1		
77353	Boss 2425	8 56.9	− 0 6	5.8	G9	.091	3	+ 73.7	1.7		
77408	Cin. 1070	8 57.2	+33 16	7.1	F5s	.40	3	+ 70.5	2.0		
77800	Boss 2434	8 59.6	+67 16	5.3	M0	.050	3	+ 18.7	0.4	+13.4	L
77938	C.D. −31°6877	9 0.3	−32 3	7.7	M:	....	3	− 3	1		
78235	Boss 2444	9 2.0	+30 3	5.4	G5	.028	3	− 14.2	1.5	−12.6	L
78732	2456	9 4.7	− 8 23	5.7	G7	.036	3	+ 26.5	1.5		
79354	2474	9 8.4	+57 9	5.5	M0	.036	3	− 31.2	1.9	−30.4	L, V
80024	2494Br	9 12.3	+35 47	5.8	A5	.058	5	+ 17	3	+25.4	V
80441N	βG.C. 5030N	9 14.8	+38 37	7.0	F4s	.047	3	+ 0.6	1.2		
80441S	5030S	9 14.8	+38 37	7.2	F2s	0.047	4	− 1.9	±1.1		

									km/sec.	km/sec.	km/sec.	
80499	Boss	2506	$9^h15^m.0$	−11° 33′	4.9	G5	0″.021	3	− 5.8	±2.2	− 0.9	L
80536		2508	9 15.3	+25 35	7.3	G0	.160	3	− 38.6	1.8		
81809		2535	9 22.8	− 5 38	5.4	G1	.233	3	+ 52.3	1.2	+53.8	L
81937		2540	9 23.7	+63 30	3.8	A5n	.117	5	− 8	3	− 8	L
82087		2543	9 24.7	+34 6	6.0	G8	.065	6	+ 2.0	0.9	+ 1.4	V
82198		2546	9 25.5	+35 33	5.5	M1	.130	3	+ 37.7	1.0		
....	B.D. +36°	1970	9 25.8	+36 47	9.3	M2	.56	4	+ 21	3		
82309	βG.C.	5124Br	9 26.1	+20 27	7.4	G9	.118	3	− 10.6	2.4		
82522	Boss	2561	9 27.4	+36 56	6.4	K4	.059	3	− 17.4	1.5		
82621		2565	9 28.0	+52 30	4.6	A0	.073	5	+ 22	4	+20	L
82741		2570	9 28.8	+40 4	5.0	G5	.031	3	− 11.3	0.4	−11.9	L
82819	B.D. + 8°	2243	9 29.4	+ 8 38	8.1	M4	.019	3	+ 45	2		
83069	Boss	2578	9 30.8	+31 37	5.7	M2	.044	3	− 17.9	1.5	−22.2	V
83489		2591	9 33.7	+69 42	5.7	K0	.093	3	− 9.0	1.8		
83506		2592	9 33.8	+72 42	5.4	G6	.042	3	− 16.5	1.5	−17.4	L
83754		2600	9 35.5	−13 53	5.0	B3	.031	3	+ 13	3	+17	L
83805		2601	9 35.8	+40 13	5.5	G5	.076	3	+ 32.4	1.7	+28.7	L
84035	Cin.	1153	9 37.1	+43 10	8.1	K5	.819	3	− 13.5	1.5		
84406	Boss	2617	9 39.9	+63 43	6.9	K0	.192	3	+ 7.5	1.9		
84453		2620	9 40.3	+45 35	6.8	K0	.155	3	− 43.8	2.1	−44.4	V
85029		2633	9 44.1	+40 6	6.8	M2	0.016	4	+ 8.6	1.5		
....	Cin.	1167	9 46.2	−11 49	9.4	M2	1.848	4	+ 61	3		
....	B.D. +63°	869	9 48.8	+63 16	8.7	M1	0.600	3	+ 10	1		
86012	Boss	2662	9 50.7	+32 51	6.6	F3s	.039	3	+ 9.1	0.5	+ 6.8	V
86513		2675	9 53.8	+30 7	5.9	G9	.112	3	− 0.1	1.8		
87443	βG.C.	5304Br	9 59.9	+31 35	7.9	A9n	.042	3	+ 20	1		
87696	Boss	2692	10 1.5	+35 44	4.5	A5	.054	3	− 14	2	−12:	L
88218		2704	10 5.2	−35 22	6.3	F9	.436	3	+ 40.9	0.7		
88547		2714	10 7.6	+ 5 7	5.9	G9	.059	3	+ 32.2	1.3		
....	B.D. +10°	2122	10 7.9	+10 4	9.2	K2	.626	3	− 17	±1		

TABLE I—*Continued*

H.D.	Star	α 1900	δ 1900	m	Sp.	μ	No.	v	P.E.	Other Determinations v	Other Determinations Auth.
								km/sec.	km/sec.	km/sec.	
88742	Boss 2718	$10^h\ 9^m0$	−32° 32′	6.4	G0	0″.356	3	+ 40.8	±0.4		
88986	2727	10 10.8	+29 11	6.5	F9	.108	3	+ 31.5	.7	+28.8	V
89056	2731	10 11.3	+14 14	5.7	M2	.035	3	+ 2.2	0.4		
89254	2735	10 12.7	− 7 34	5.4	F2s	.161	3	+ 20.7	2.3	+12.6	L
89269	2736	10 12.8	+44 33	6.7	G4	.311	3	− 10.5	1.1	− 6.9	V
89668	Cin. 1246	10 15.7	− 0 58	8.9	M0	.679	4	+ 35	2		
89777	B.D. −16°3030	10 16.5	−16 33	9.1	K1	.54	3	+ 44	3		
90254	Boss 2766	10 20.0	+ 9 18	5.9	M3	.045	5	− 20.3	1.3		
90277	2768	10 20.2	+34 18	4.8	F2	.107	3	+ 12.4	2.1	+13.7	L
90362	2770	10 20.7	− 6 33	5.8	M2	.189	3	+ 31.9	0.8		
....	B.D. +46°1635	10 25.5	+46 3	9.3	M0	.837	3	+ 25	3		
91550	Boss 2815	10 29.3	−23 14	5.3	K5	.009	2	− 3.9	0.5	− 5.3	L
91881	βG.C. 5491Br	10 31.6	−26 11	6.2	F2s	....	3	− 20.8	2.2		
92523	Boss 2844	10 35.9	+69 36	5.2	K4	.023	2	+ 1.7	1.7	− 0.6	L
....	B.D. +47°1806	10 38.1	+46 49	9.1	G0	....	3	− 15	2		
92940	+33°2022	10 38.8	+33 9	7.3	A9	.033	6	− 6	2		
92841	Boss 2858Br	10 38.2	+ 5 16	6.0	K2	.045	5	− 9.1	1.5	− 3.2	V
93257	2869	10 41.0	+19 25	5.6	K2	.099	3	− 6.3	0.7		
93291	2870	10 41.1	+14 43	5.6	G5	.152	3	+ 34.2	1.8		
94388	2902	10 48.6	−19 36	5.3	F5	.253	3	+ 0.8	1.9	− 4.5	L
94402	2903	10 48.6	− 1 36	5.7	G6	.094	3	+ 15.8	1.7		
94469	βG.C. 5599	10 49.2	+21 19	8.4	F1s	....	4	− 44	3		
94481	Boss 2906	10 49.3	−13 14	5.8	G4	.029	3	+ 4.9	0.9		
95241	2924	10 54.7	+43 27	6.1	F7	0.178	3	− 8.4	1.0	− 6.4	V
96074	B.D. +66° 697	10 59.8	+66 25	7.7	G5	....	4	− 10.5	±2.6		

									km/sec.	km/sec.	km/sec.	
....	βG.C.	5679Br	11h 2m.1	+53° 21′	7.1	F7	0″.044	3	− 36.6	±2.3		
96700..........	Cin.	1356	11 3.2	−29 38	6.5	G0	.546	3	+ 10.7	0.8		
97033..........		1359	11 5.3	+66 34	9.0	G6	.356	4	− 2	2		
97233..........		1364	11 6.5	−14 26	9.3	K6	.92	3	− 2	1		
97561..........	Boss	2967	11 8.4	+20 41	6.9	G3	.408	3	+ 44.9	1.7	+44.2	V
97605..........		2973	11 8.8	+ 8 36	5.9	K3	.130	3	+ 18.6	2.0	+15.8	V
....	Cin.	1375	11 12.2	− 1 26	9.0	M0	.53	3	+ 4	3		
99167..........	Boss	3002	11 19.6	−10 19	5.1	M1	.043	2	+ 5.1	0.2	+ 1.8	L
99196..........		3004	11 19.8	+11 59	6.0	K4	.116	4	+ 37.7	1.0		
99651..........		3020	11 22.8	− 1 9	6.3	G8	0.042	3	− 9.1	0.3		
....	Cin.	1412	11 23.3	+ 8 6	9.7	G8	1.16	3	+ 1	2		
99984..........	Boss	3028	11 25.1	+43 43	5.9	F2s	0.088	3	− 29.6	0.5		
99998..........		3029	11 25.2	− 2 27	5.1	K5	.026	3	+ 19.8	1.7	+18.5	L
100180..........		3032Ft	11 26.6	+14 55	8.4	M0	.387	4	− 10	1		
100563..........		3044	11 29.2	+ 3 37	5.8	F6	.215	3	+ 7.3	0.5		
101853..........		3083	11 38.3	+42 17	6.8	G8	.031	5	+ 3.9	0.8	+ 1.8	V
101933..........		3086	11 38.8	− 6 7	6.2	G9	.083	5	− 2.5	0.8		
102590..........	βG.C.	5926	11 43.5	+14 50	5.9	A6n	.12	3	+ 6	3		
102942–3..........	B.D. +34°	2264	11 46.0	+33 56	6.1	F0s	....	3	+ 1.8	0.8	− 0.6	V
103026..........	Boss	3110	11 46.6	−30 16	6.0	F6	.310	3	+ 33.4	1.0		
103246..........	βG.C.	5951Br	11 48.3	+74 19	6.8	F7s	.090	3	− 35.3	1.3		
103484..........	Boss	3121	11 49.9	+ 9 0	5.6	G6	.030	3	− 9.1	0.5		
103596..........		3124	11 50.6	−27 55	6.1	K5	.032	3	+ 7.7	0.1		
103945..........		3128	11 53.1	+ 4 2	6.9	M4	.009	3	− 22.4	2.2		
104055..........		3132	11 53.9	+ 1 5	6.5	K3	.070	3	+ 11.4	1.6		
104216..........		3136	11 55.1	+81 25	6.4	M4	.068	3	+ 31.2	1.9		
104731..........		3148	11 58.5	−41 52	5.3	F5	.344	2	+ 38.1	0.0	+37.4	L
104755..........		3149	11 58.6	+ 6 7	6.5	F3s	.171	3	+ 1.6	0.9	+ 7.6	V
104800..........	Cin.	1492	11 59.0	+ 3 55	9.3	F9	.567	3	+ 11	3		
104985..........	Boss	3156	12 0.2	+77 28	6.0	G9	0.169	3	− 19.0	±0.8	−18.7	V

TABLE I—*Continued*

H.D.	Star		α 1900	δ 1900	m	Sp.	μ	No.	v	P.E.	Other Determinations	
											v	Auth.
									km/sec.	km/sec.	km/sec.	
....	B.D.	+28°2078	12h 1m.1	+28° 3′	9.1	F6	0″.41	3	− 3	±1		
105390		+ 0°2897	12 3.0	+ 0 11	8.9	F6	......	4	− 19.4	1.4		
105702	Boss	3171	12 5.0	+ 6 22	5.7	cF4	.166	4	− 10.3	1.3	− 9.2	V
105791	Cin.	1515	12 5.6	+66 13	8.7	F2	.31	3	+ 66	2		
105963N	βG.C.	6064N	12 6.5	+53 59	7.5	K2	.221	4	− 9.5	0.8		
105963S		6064S	12 6.5	+53 59	7.7	G9	.221	3	+ 4.0	2.2		
106057	Boss	3181	12 7.1	+21 6	5.7	G7	.033	3	− 24.4	2.1	−25.8	V
106365	βG.C.	6082Br	12 9.1	+33 20	6.8	K2	.128	3	− 10.3	1.5		
107054–5	Cin.	1541	12 13.5	+30 49	6.1	A5n	.148	4	− 31	1		
107113	Boss	3204	12 13.9	+86 59	6.3	A8s	.210	3	− 6	1		
....	B.D.	+29°2279	12 14.5	+28 56	9.5	M2	.64	4	− 26	2		
107341	Boss	3212	12 15.2	+38 27	6.7	G6	.056	3	+ 4.9	0.4		
107325		3214	12 15.3	+27 11	5.7	K2	.138	3	− 9.7	0.9		
107465		3219	12 16.0	+58 25	5.7	K4	.083	3	− 41.3	1.0	−44.0	V
107612	B.D.	+17°2469	12 17.0	+17 17	6.6	A3s	......	4	+ 3	2		
107966	Boss	3231	12 19.3	+26 39	5.1	A2	.033	3	+ 3	2	− 2.5	L
108153	Cin.	1566	12 20.4	+32 26	9.3	K4	.468	3	− 20	3		
108225	Boss	3235	12 20.9	+39 34	5.2	G6	.086	4	− 4.1	1.1	− 2.8	L, V
108506		3247	12 22.7	− 4 4	6.0	Fon	.081	4	− 14.0	4.3		
108574	βG.C.	6179Br	12 23.3	+45 21	7.4	F8	......	3	− 0.1	0.4		
108575		6179Ft	12 23.3	+45 21	8.0	G2	......	3	+ 0.8	0.3		
108680	Boss	3252	12 24.0	− 1 53	7.6	M4	.049	3	− 35.7	0.7		
108767		3256	12 24.7	−15 58	3.1	A0	.251	3	+ 1	4	− 4:	L
108821		3259	12 25.1	−23 9	5.9	M0	.030	3	− 11.6	1.8		
108910		3264	12 25.7	− 3 31	7.1	K3	0.078	3	+ 83.9	±0.4		

								km/sec.	km/sec.	km/sec.	
....	B.D. + 9°2636	12h 26m.3	+ 9° 22′	9.1	M1	0″.96	3	+ 21	±2		
109141........	Boss 3273	12 27.4	−13 18	5.7	A9n	.154	3	− 1	1		
109628p........	βG.C. 6216p	12 31.0	+11 57	8.5	F7	.300	5	+ 23	2		
109628f........	6216f	12 31.0	+11 57	8.5	G0	.300	3	+ 17	1		
109742........	Boss 3291	12 32.0	+17 38	5.8	K5	.050	3	− 8.0	0.8		
112943........	Cin. 1661	12 55.2	− 2 10	9.1	M0	.73	3	− 13	1		
113101........	1667	12 56.2	− 7 54	8.7	K0	.493	7	− 31	3		
113415........	Boss 3387	12 58.4	−20 3	5.7	F8	.141	3	+ 33.5	1.5		
113865........	B.D. +29°2365	13 1.4	+29 34	6.4	A4n	....	4	+ 2	1		
113848........	Boss 3397	13 1.5	+21 41	6.0	F0n	.089	3	+ 1.9	0.8	− 1.1	V
114060Br........	βG.C. 6393Br	13 2.9	+24 32	7.6	G5	.27	7	− 4.1	1.4		
114060Ft........	6393Ft	13 2.9	+24 32	8.0	G7	.27	3	+ 0.5	1.5		
114094........	B.D. + 4°2696	13 3.2	+ 4 19	9.5	G6	.54	3	− 57	3		
114300........	+18°2696	13 4.6	+18 0	8.7	M0	.120	3	− 25	2		
114613........	Boss 3421	13 6.5	−37 16	4.9	G3	.390	3	− 12.8	1.8	−15.8	L
114703........	Cin. 1693	13 7.0	+68 2	8.8	K0	.75	4	− 13	2		
114692........	C.D. −34°8720	13 7.0	−34 13	7.6	F7	.509	4	+ 1.3	1.6		
114729........	Boss 3425	13 7.2	−31 20	6.7	G0	.380	4	+ 63.3	2.5		
114946........	3430	13 8.8	−19 24	5.6	G4	.198	3	− 44.5	2.1		
115079........	3435	13 9.7	−10 50	7.8	G3	.383	4	+ 7.1	1.3		
115478........	3445	13 12.3	+14 12	5.4	K2	.027	3	− 27.2	0.9	−25.6	L
116303........	3466	13 17.7	+44 26	6.4	A5s	.075	3	− 2	1		
116713........	3477	13 20.3	−39 14	5.2	K0p	.203	3	+ 64.2	1.6	+69.4	L
116870........	3481	13 21.4	−12 11	5.6	K5	.137	3	− 29.0	1.6		
116976........	3482	13 22.1	−15 27	4.9	K1	.127	3	− 16.2	2.2	−13.7	L
117421........	B.D. − 7°3631	13 25.0	− 8 5	9.6	F4	....	3	− 33	3		
117448........	+70° 741	13 25.3	+70 39	7.5	K0	.039	5	− 28.5	2.1		
117697........	+ 9°2773	13 27.0	+ 9 30	7.9	F8	.019	4	+ 8.6	1.7		
117939........	C.D. −38°8635	13 28.7	−38 23	7.1	G4	.500	4	+ 86.8	2.2		
118036........	βG.C. 6530Br	13 29.2	+ 0 12	7.4	K1	0.234	3	− 2.6	±0.7		

TABLE I—*Continued*

H.D.	Star	α 1900	δ 1900	m	Sp.	μ	No.	v	P.E.	Other Determinations v	Other Determinations Auth.
								km/sec.	km/sec.	km/sec.	
118054	Boss 3507m	13h 29m.4	−12° 42′	5.8	A2s	0″.067	4	− 20	±3		
119126	3533	13 36.3	+23 0	5.8	G5	.041	3	+ 5.5	1.1	+ 3.8	V
119217	B.D. + 0°3090	13 36.8	+ 0 24	9.3	M1	.545	3	+ 48	2		
119756	Boss 3544	13 40.0	−32 32	4.4	F1s	0.489	3	− 17.1	1.1	−14.9	L
	Cin. 1784	13 40.2	+18 20	9.0	M1	1.86	4	+ 27	1		
120052	Boss 3553	13 42.0	−17 21	5.8	M2	0.065	3	+ 63.4	0.4		
120198	3561	13 42.9	+54 56	5.5	A2s	.015	5	− 5	2	− 5.3	V
120237	Cin. 1796	13 43.2	−35 12	6.5	F8	.57	3	+ 6.3	1.1		
120348	Boss 3568	13 43.9	+42 33	6.8	K2	.075	3	− 1.2	0.2		
120420	3570	13 44.1	+31 41	5.8	G7	0.043	3	+ 12.5	0.1	+10.5	V
120467	B.D. −21°3781	13 44.4	−21 36	7.9	K6	1.77	3	− 35.3	0.2		
120539	Boss 3573	13 45.0	+21 46	5.1	K4	0.017	2	− 1.7	0.5	− 3.1	L
121849	Cin. 1826	13 52.8	−33 30	8.4	G2	.59	3	+ 64	3		
121953	1828	13 53.7	+65 51	7.6	G2	.291	4	− 28.4	0.8		
122066	Boss 3607	13 54.4	−24 31	5.8	F2	.235	3	− 17.3	2.7		
	B.D. +34°2476	13 54.8	+34 22	9.3	A5sp	.54	3	−164	2		
122408	Boss 3612	13 56.6	+ 2 2	4.3	A2	.032	5	− 4	4	− 5	L
123453	βG.C. 6725Br	14 2.6	−12 27	7.4	F4	.141	3	+ 14.1	1.0		
123934	Boss 3632	14 5.4	−15 50	5.1	M3	.027	3	+ 19.5	1.9	+17.6	L
124640Br	βG.C. 6776Br	14 9.7	+55 48	8.2	K6	.341	3	− 16	1		
124640Ft	6776Ft	14 9.7	+55°48′	8.5	K6	.341	3	− 18	2		
124679	Boss 3655	14 10.0	+10 34	5.4	G6	.172	3	+ 15.7	2.1	+17.0	L
124757	βG.C. 6780m	14 10.3	+ 3 35	7.0	F8	.194	5	− 44.8	1.2		
125040Br	6795Br	14 11.9	+20 35	6.4	F6	.181	3	− 10.1	1.3		
125140Br	6801Br	14 12.2	+57 7	8.5	G1	0.044	4	− 1	±1		

									km/sec.	km/sec.	km/sec.	
125140Ft	βG.C.	6801Ft	14h12m2	+57° 7′	9.8	F0	0″.044	4	− 4	±2		
125560	Boss	3681	14 15.0	+16 46	5.0	K4	.155	3	− 8.1	0.4	− 7.3	L
125906	βG.C.	6837S	14 17.3	− 7 18	6.8	F8	0.125	3	− 34.8	1.5		
....	Cin.	1894	14 21.1	+24 6	9.0	M2	1.39	4	+ 14	2		
....		1895	14 21.1	+24 6	9.1	M2	1.40	5	+ 5	2		
126927	Boss	3711	14 23.4	− 6 27	5.7	K5	0.075	3	− 49.7	0.8		
127339	Cin.	1905	14 25.6	− 8 12	9.3	M1	1.26	3	− 27	2		
127506	B.D.	+36°2500	14 26.7	+35 53	8.2	K6	0.51	3	− 12	2		
127739	Boss	3721	14 28.0	+22 42	6.0	A9s	.133	5	− 12	2		
127930	βG.C.	6923Br	14 29.0	+49 38	7.8	F5s	....	3	− 4	1.1		
128165	Boss	3728	14 30.2	+53 20	7.4	K6	.316	3	+ 13.7	1.7		
....	Cin.	1920	14 30.9	+34 11	9.0	M0	.76	4	− 53	2		
128333	Boss	3733	14 31.2	+49 48	5.9	M1	.067	3	− 20.4	1.3		
128967	βG.C.	6949Br	14 34.9	+27 15	8.4	F1n	....	4	− 10.1	1.9		
129246–7	Boss	3752m	14 36.4	+14 9	3.8	A2n	.061	2	− 6	1	− 3:	L
129312		3753	14 36.7	+ 8 35	5.0	G0	.010	3	− 21.1	1.3	−22.6	L, V
129580Ft	βG.C.	6977Ft	14 38.2	+58 22	8.0	G4	.244	4	− 15.6	1.2		
....	B.D.	+ 6°2932	14 38.4	+ 6 15	9.5	G0	.93	3	−138	6		
129846	Boss	3764	14 39.8	+40 53	5.8	K3	.024	3	+ 16.6	1.1	+10.7	V
....	Cin.	1948	14 41.7	+16 56	8.9	K6	.97	4	+ 47.4	1.8		
130871		1960	14 45.5	+ 7 14	9.4	K5	.603	3	− 32	1		
130991	B.D.	−20°4107	14 46.0	−20 12	7.5	G8	....	3	− 7.1	1.1		
131111	Boss	3795	14 46.5	+37 41	5.5	G7	.231	4	− 64.8	1.8	−66.7	L, V
131316Br	βG.C.	7043Br	14 47.8	+45 1	8.0	F5s	....	3	− 27.8	2.6		
131473Br		7049Br	14 48.6	+16 6	6.4	F9	.017	3	+ 20.8	1.6		
132029Br		7065Br	14 51.7	+32 42	6.1	A3n	....	5	− 11	2		
132833	Boss	3828	14 56.1	− 2 22	5.7	M1	.048	4	− 15.2	1.7		
132933Br		3831Br	14 56.7	+ 0 15	5.9	M2	.030	3	− 35.7	0.6	−33.6	V
133029	B.D.	+47°2192	14 57.2	+47 40	6.2	A0	....	3	− 16	1	−12.6	V
133392	Boss	3841	14 59.1	+35 36	5.7	G8	0.050	3	− 26.2	±1.2		

TABLE I—*Continued*

H.D.	Star	α 1900	δ 1900	m	Sp.	μ	No.	v	P.E.	Other Determinations v	Other Determinations Auth.
								km/sec.	km/sec.	km/sec.	
134088	Cin. 2010	15^h 2^m9	$-7°31'$	8.1	F8	0″.484	5	−59.2	±2.1		
....	2012	15 3.1	+25 18	9.2	Mo	.961	3	−65	4		
134190	Boss 3856	15 3.4	+54 56	5.2	G5	.044	3	+15.7	1.3	+16.4	L, V
....	B.D. +32°2547	15 3.6	+32 47	9.5	Go	.59	4	−63	3		
134285Br	βG.C. 7136Br	15 3.9	+ 2 4	7.8	F3s	....	3	+10.6	0.5		
134329	Boss 3858	15 4.0	−23 36	6.8	K5	.046	3	−14.1	3.2		
134320	3859	15 4.1	+26 41	5.7	K2	.029	3	+24.2	1.8	+18.3	V
134335	3860	15 4.2	+25 29	5.9	K1	.017	3	−17.6	1.3	−16.2	V
134987	3869	15 7.6	−24 56	6.4	G3	.401	3	+2.4	1.0		
....	B.D. − 3°3746	15 8.8	− 3 26	9.2	Mo	.69	3	−107	1		
135363	+76° 552	15 9.6	+76 34	9.2	K2	.211	3	−1	1		
135402	Boss 3881	15 9.8	+38 38	6.4	K1	.048	3	−62.5	2.4		
136136N	βG.C. 7212N	15 13.9	+44 10	8.5	G7	.034	3	−45	2		
136136S	7212S	15 13.9	+44 10	8.5	G5	.034	4	−17	2		
136138	Boss 3894	15 13.9	+20 56	5.7	G3	.045	3	−7.6	1.3		
136160Br	βG.C. 7210Br	15 13.9	+10 48	6.7	F5	....	3	−45.5	1.9		
136176	7214m	15 14.1	+27 12	6.6	F7s	0.117	3	−19.6	0.9		
....	B.D. − 7°4003	15 14.2	− 7 21	9.8	M5	1.33	4	−30	2		
136526p	βG.C. 7226p	15 16.1	+31 3	8.7	F3	....	3	−43	1		
137443	Boss 3930	15 21.0	+63 42	5.8	K5	0.114	3	−47.3	1.7	−45.7	V
137704	3933	15 22.4	+34 41	5.9	K5	.120	3	−49.1	0.6	−47.9	V
137826	Cin. 2067	15 23.1	+66 54	9.0	G5	.28	4	−34	3		
138481	Boss 3945	15 27.3	+41 10	5.2	Mo	.018	3	−7.6	1.1	−10.0	L
139153	3967	15 31.6	+39 21	5.4	M2	.029	4	−19.0	1.4	−19.2	L
139216	3969	15 31.8	+15 26	6.8	M6	0.011	5	−26.2	±2.1		

									km/sec.	km/sec.	km/sec.	
139307	Boss	3972	15h 32m.2	+50° 2′	7.5	K5	0″.021	3	− 11.1	±0.8		
139669		3982	15 34.4	+77 41	5.3	K5	.044	3	− 26.5	1.9	−25.4	L, V
140027		3992	15 36.4	+16 21	6.0	G5	.033	4	+ 3.4	1.7	+ 3.2	V
140160		3993	15 37.1	+13 10	5.3	Aop	.044	4	+ 6	1		
140716		4003	15 40.0	+32 50	5.6	G9	.043	3	− 4.3	1.6	− 3.8	V
140901	Cin.	2109	15 41.0	−37 36	6.1	G5	.525	3	− 3.5	0.9		
141003	Boss	4009	15 41.6	+15 44	3.7	A1n	.091	5	+ 1.0	3	− 7	L
141513		4016	15 44.4	− 3 7	3.6	A0	.092	5	− 9	2	−11	L
141653		4021	15 45.1	+62 54	5.1	A2	.070	7	− 4	2	− 5	L
141680		4023	15 45.2	+ 2 30	5.3	G6	.064	5	− 2.5	1.0	− 3.7	L
142980		4060	15 52.6	+14 42	5.7	K3	.134	3	− 67.4	0.7	−69.4	V
143435		4069	15 55.3	+36 56	5.7	K5	.031	4	+ 10.4	1.1		
143553		4074	15 55.9	+ 4 42	5.9	G7	.081	3	− 3.6	0.6		
143787		4078	15 57.3	−25 35	5.1	K3	.080	3	− 38.5	0.8	−38.8	L
144087	βG.C.	7488Br	15 59.0	−11 10	7.4	G5	......	3	− 33.3	1.4		
144204	Boss	4085	15 59.5	+53 12	6.2	K5	.038	3	− 6.8	1.1		
145000		4102	16 3.6	+17 19	6.5	K1	.062	6	+ 38.0	1.2		
145675		4124	16 7.2	+44 5	6.5	G9	.336	3	− 5.0	1.2		
145958		4132S	16 8.6	+13 48	7.8	K0	.459	6	+ 17.7	1.5		
146698	B.D.	+19°3077	16 12.5	+19 5	7.6	K5	.017	3	+ 9.4	0.7		
146834	Boss	4150	16 13.3	−19 58	6.4	G6	.026	8	+ 8.5	1.2		
147025		4154	16 14.2	+26 8	6.6	G4	.009	4	− 10.7	1.1	− 8.4	V
148048		4181	16 20.4	+75 59	5.0	A8n	.261	4	− 10	1	− 8	L, V
148211	Cin.	2193	16 21.3	−21 54	7.6	F8	.417	3	− 19.1	0.9		
148493	βG.C.	7636Br	16 23.4	+21 3	8.3	F9	.138	3	+ 8.9	0.5		
148604	Boss	4197	16 24.1	−14 20	5.8	G2	.025	3	− 31.9	0.7		
148605		4198	16 24.1	−24 54	4.9	B3	.028	3	− 2	4	− 5	L
148704	Cin.	2200	16 24.8	−38 48	7.5	K0	.563	3	− 59.1	0.6		
148783	Boss	4201	16 25.3	+42 6	5.0	M6	0.028	3	+ 3.5	1.0	+ 3.3	L
148980Br	βG.C.	7655Br	16 26.7	+ 5 39	7.6	A9	......	3	− 14	±2		

TABLE I—*Continued*

H.D.	Star		α 1900	δ 1900	m	Sp.	μ	No.	v	P.E.	Other Determinations v	Other Determinations Auth.
									km/sec.	km/sec.	km/sec.	
149303Br	Boss	4214Br	16h 28m8	+45° 49′	5.6	A1n	0″.028	5	− 13	±3	−18.5	V
149303Ft		4214Ft	16 28.8	+45 49	8.2	F5	.028	4	− 16.9	1.6		
149957	Cin.	2217	16 32.9	+31 19	9.5	K6	.59	3	− 7	0		
....	B.D.	+31°2877	16 33.4	+31 25	9.2	K5	....	3	− 20	1		
150379	Boss	4237	16 35.6	+ 4 24	6.9	A5n	.023	4	− 30	1		
151188	βG.C.	7748m	16 40.8	+43 41	8.3	K5	....	3	− 7	0		
151216	B.D.	+33°2775	16 41.0	+33 30	8.8	K1	.059	5	− 16	2		
151482		+34°2839	16 42.5	+33 59	8.1	A3n	.02	6	+ 1	2		
151937	Boss	4279	16 45.3	+30 8	6.7	G7	.102	4	− 42.7	2.0		
152107		4284	16 46.3	+46 9	4.9	A4s	.076	3	− 4	1	+ 0.8	L
152334		4292	16 47.6	−42 11	3.8	K5	.266	2	− 15.3	0.4	−18.8	L
152326		4294	16 47.6	+24 49	5.2	K2	.016	3	− 15.5	1.1	−15.9	L
153301	βG.C.	7814Br	16 53.5	+15 18	7.8	G5	....	3	− 11.0	2.0		
153344	Boss	4317	16 53.8	+62 16	7.0	G2	.321	4	− 82.6	2.0		
....	B.D.	+25°3173	16 54.1	+25 55	9.4	M2	.52	3	+ 11	4		
153834	Boss	4329	16 56.7	+22 47	5.7	K2	.030	3	+ 10.4	0.5	+11.0	V
153956		4330	16 57.5	+56 50	6.1	K2	.054	3	− 15.4	1.1		
154088		4333	16 58.1	−28 26	6.7	G8	.291	3	+ 17.2	1.8		
154228		4340	16 59.0	+13 45	5.9	A2s	.054	5	− 37	1		
154278		4341	16 59.3	+13 43	6.1	G7	0.135	4	+ 47.0	1.1		
154363		4342	16 59.8	− 4 54	7.9	M0	1.464	3	+ 28.2	0.5		
....	B.D.	− 4°4226	17 0.0	− 4 55	9.3	M3	1.465	3	+ 30	4		
154733	Boss	4350	17 2.1	+22 13	5.7	K5	0.122	4	− 95.4	0.9	− 97.2	V
154759	βG.C.	7873Br	17 2.4	+47 6	8.1	K2	.046	3	− 52.9	0.4		
155644	Boss	4366	17 7.7	+10 42	5.6	M2	0.036	3	+ 25.3	±1.9		

									km/sec.	km/sec.	km/sec.	
155876	B.D.	+45°2505	17ʰ 9ᵐ2	+45° 50′	9.6	M4	1″.590	4	− 19	±3		
....	Cin.	2297	17 9.9	+42 28	9.4	M1	1.061	6	+ 6	3		
156681	Boss	4389	17 13.9	+10 58	5.3	K5	0.099	2	+ 42.7	0.2	+39.0	L
156890	βG.C.	7962Br	17 14.9	+60 49	6.7	A7n	.041	3	− 26	1		
157049	Boss	4400	17 15.9	+18 10	5.2	M2	.051	4	− 47.0	1.3	−46.1	L, V
157325		4408	17 17.5	+46° 20′	5.8	Mo	.050	4	− 57.2	0.9		
157370		4409	17 17.8	+71 54	6.8	K2	.018	3	− 3.9	0.9		
157906Br	βG.C.	8009Br	17 21.0	+47 22	7.8	F6s	......	4	− 26.9	1.4		
157910	Boss	4422	17 21.0	+37 2	6.5	G5	.053	3	− 14.8	1.5	−18.2	V
158116Br	βG.C.	8017Br	17 22.4	+29 33	7.0	A8	......	4	− 25	1		
....	Cin.	2326	17 22.9	+31 8	9.1	G7	.421	4	− 73	2		
158225	B.D.	+31°3026	17 23.0	+31 21	7.0	F4	......	4	+ 0.1	0.8		
158226	Cin.	2328	17 23.0	+31 10	8.1	Go	.32	4	− 71	1		
159332	Boss	4446	17 29.0	+19 20	5.6	F5	.095	4	− 61.0	2.1		
159466		4451	17 29.8	+13 14	6.7	G4	.036	3	− 60.1	0.7		
161074		4486	17 38.4	+24 37	5.6	K5	.131	3	− 27.5	0.8	−28.0	V
161471		4492	17 40.6	−40 5	3.1	F6	.004	6	− 21.9	1.7	−26.7	L
161848	Cin.	2366	17 42.8	+ 4 59	9.0	K3	.70	3	− 93	2		
162076	Boss	4506	17 44.1	+20 36	5.8	G5	.022	3	− 28.6	1.1	−25.4	V
162555		4510	17 46.5	+29 21	5.6	G7	.049	3	− 13.7	0.4	−14.5	V
163608	B.D.	+45°2621	17 51.8	+45 14	8.0	Ao	.023	3	− 23	3		
163609	βG.C.	8242Br	17 51.8	+21 30	7.5	G3	......	3	− 32.5	1.7		
165625	Boss	4578	18 1.8	+22 13	5.3	M2	.023	5	− 19.8	1.1	−18.6	L, V
165945	B.D.	−15°4832	18 3.3	−15 33	9.2	A4	......	4	− 16	2		
167618	Boss	4617	18 10.8	−36 48	3.2	M4	.216	3	+ 5.2	1.3	+ 0.1	L
168322		4624	18 13.9	+40 54	6.1	G3	.180	3	− 73.7	0.9		
168387		4626	18 14.3	+ 7 13	5.6	K2	.063	3	− 7.3	.9	− 8.7	V
168415		4627	18 14.4	−15 52	5.7	K5	.047	3	+ 30.1	.9		
168653		4634	18 15.9	+68 43	6.1	Ko	.062	4	− 10.7	.8		
169110		4649	18 18.0	+23 14	5.7	Mo	0.076	3	− 57.4	±0.8		

TABLE I—*Continued*

H.D.	Star		α 1900	δ 1900	m	Sp.	μ	No.	v	P.E.	Other Determinations	
											v	Auth.
									km/sec.	km/sec.	km/sec.	
169746	B.D.+	43°2970	18h21m1	+43°51′	7.0	M2	......	3	−46.7	±0.6		
170397	Boss	4675	18 24.1	−14 39	6.0	A2	0″.022	4	−16	2		
170740		4687	18 25.9	−10 52	5.8	B3	.031	3	−13	1		
171115		4698	18 27.8	−24 6	5.7	K5	.018	3	−14.6	1.3		
171586	βG.C.	8654	18 30.7	+4 51	6.7	A4p	.05	3	−11	1		
171745	Boss	4708	18 31.3	+23 31	5.8	G7	.021	3	+16.4	1.6		
172546		4726	18 35.8	−23 56	6.1	A8	.043	3	+1	2		
172586Br	βG.C.	8721Br	18 35.8	+24 37	8.0	G5	......	3	−32.0	2.1		
172713	Boss	4728N	18 36.6	+52 15	7.4	G0	.012	4	+17.8	1.9		
173460		4743	18 40.3	−22 30	5.8	K5	.026	4	−3.1	1.1		
174224	βG.C.	8830	18 44.4	+16 8	8.1	F5s	.076	3	−61.3	2.1		
......	Cin.	2463	18 44.5	+17 20	9.0	M0	.579	4	−17	2		
174589	Boss	4773	18 46.1	−3 26	6.0	A5n	.037	3	+12	2		
174980		4782	18 48.3	+73 58	5.4	G8	.081	3	+4.0	0.9	+2.8	L, V
175518	Cin.	2471	18 50.6	−5 52	8.2	G8	.415	6	−76.9	2.6		
176485	βG.C.	8954Br	18 55.3	+12 45	7.1	K5	.035	3	−2.6	1.4		
176982		8986Br	18 57.6	−0 51	7.9	G5	.131	3	−11.2	1.2		
177095	Cin.	2487	18 58.0	−20 35	9.4	G2	.71	3	+78	2		
177483	Boss	4855	18 59.8	+52 7	6.4	G8	.029	3	+4.7	0.3		
177758	Cin.	2490	19 0.9	−12 2	7.1	F8	.422	3	−2.5	1.3		
177749Br	βG.C.	9021Br	19 0.9	+6 24	6.9	F4	......	3	−17.8	1.8		
178496	Cin.	2497	19 3.7	−21 37	8.7	G3	.468	4	−42	1		
178770	Boss	4877	19 4.8	+39 0	7.6	M6	.007	3	−17.2	0.4		
178911	βG.C.	9078Br	19 5.3	+34 26	6.5	G0	.191	3	−41.7	1.3		
179406	Boss	4883	19 7.2	−8 6	5.4	B3	0.017	3	−15	±5	−19:	L

								km/sec.	km/sec.	km/sec.	
179484	βG.C. 9114A	$19^h\ 7^m7$	+38° 37′	7.5	G4	0″.267	7	+ 27.4	±2.1		
179626	Cin. 2509	19 8.2	− 0 45	9.3	F4	.53	3	− 71	2		
180409	Boss 4901	19 11.3	−11 9	7.0	F6	.142	3	− 58.9	1.9		
180540	4903	19 11.8	−19 8	5.0	G6	.023	5	+ 15.3	3.3	+15.8	L
182477	4945	19 19.7	−14 6	5.8	K2	.086	3	− 34.6	1.8		
182900	4963	19 21.8	+12 49	5.8	F2s	.066	4	− 33.9	1.8		
182917	4966	19 21.9	+50 3	7.1	M7	.016	3	− 52.5	0.4		
183063S	βG.C. 9313S	19 22.7	−12 21	7.9	G4	....	3	− 22.0	0.6		
183473	B.D.+ 42°3351	19 24.7	+42 33	8.6	G3	....	3	− 44	2		
183492	Boss 4977	19 24.8	+14 23	5.7	Ko	.049	3	− 40.9	1.7	−40.6	V
183630	4983	19 25.4	− 3 0	5.2	M1	.016	3	− 13.2	1.6	−10.4	L
....	B.D.+ 35°3659	19 27.6	+35 58	9.5	Fos	.56	3	−172	2		
184268	Boss 4993	19 28.5	−24 4	6.7	Mo	.004	3	− 12.1	0.9		
184489	Cin. 2556	19 29.6	+ 4 21	10.5	M1	.58	3	− 52	2		
184860Br	βG.C. 9434Br	19 31.3	−10 39	8.5	K5	.391	4	+ 68	2		
184853Br	9439Br	19 31.3	+ 5 48	6.7	G6	....	3	+ 12.4	0.5		
....	B.D.+ 44°3242	19 43.4	+44 49	9.2	M2	....	4	− 36	2		
187195	Boss 5053	19 43.5	−11 7	6.2	K5	.041	4	− 37.7	1.0		
187259	5055	19 44.0	+11 34	5.7	F1s	.011	3	+ 12.6	1.4		
187691	5065	19 46.2	+10 10	5.2	Go	.273	4	− 1.4	0.9	+ 0.7	L, V
187849	5069	19 47.0	+38 28	5.4	M2	.098	3	− 37.1	1.2	−39.4	L
188041	5074	19 48.1	− 3 22	5.6	A4sp	.016	3	− 19	2		
188088	5076	19 48.3	−24 11	6.3	K5	.431	4	− 7.5	1.6		
188262	B.D.+ 16°4053	19 49.2	+16 31	7.6	F6	.008	4	− 0.9	1.1		
188326	Cin. 2596	19 49.5	+38 30	8.0	G5	.337	3	− 72	0		
188807	2599	19 51.8	−12 49	9.1	M1	.51	3	+ 3	2		
189037	Boss 5105	19 53.0	+52 10	4.8	Aon	.051	5	− 5	2	−17:	L
189063	5106	19 53.1	+60 33	7.3	M1	.012	4	− 23.0	1.6		
189245	5115	19 53.9	−33 58	5.7	F5	.337	3	− 15.2	2.4		
189763	5129	19 56.5	−27 59	4.6	M4	0.037	4	+ 6.8	±1.2	+11.5	L

TABLE I—*Continued*

H.D.	Star		α 1900	δ 1900	m	Sp.	μ	No.	v	P.E.	Other Determinations v	Other Determinations Auth.
									km/sec.	km/sec.	km/sec.	
190147	Boss	5137	19h 58m.5	+49° 50′	5.3	G9	0″.018	3	+ 2.3	±0.9	+ 0.8	L, V
190608		5151	20 0.7	+19 42	5.3	K0	.083	4	− 40.1	1.1	−40.5	L, V
190713		5152	20 1.2	+64 21	6.6	G5	.047	3	+ 9.3	1.5		
190918	βG.C.	9916F	20 2.2	+35 31	7.7	O9	.51	4	− 4	1		
190960	Boss	5154	20 2.4	+76 12	6.3	M3	.059	3	− 67.4	2.6	−69.9	V
191174		5162Br	20 3.5	+63 36	6.2	A2s	.048	3	− 19	2		
191499	βG.C.	9949Br	20 5.0	+16 30	7.7	G9	.173	3	− 34.6	0.9		
192439	Boss	5183	20 9.7	+51 10	6.4	K1	.025	3	+ 12.6	.5		
192679Ft	βG.C.	10044Ft	20 11.0	+52 49	9.1	K2	.179	3	− 35	0		
192787	Boss	5193	20 11.5	+33 26	5.8	G6	.132	3	− 10.6	1.0		
192913	B.D.+27°	3668	20 12.3	+27 29	6.7	A2s	....	5	− 15	2		
193202	Cin.	2648	20 13.9	+76 55	9.3	M0	.46	3	− 2	5		
194258	Boss	5234	20 19.7	+68 34	6.0	M5	.042	5	− 43.6	1.2		
194640	Cin.	2657	20 21.5	−31 11	6.7	G6	.55	3	− 2.4	1.0		
195006	Boss	5248	20 23.7	−22 43	6.2	M1	.029	3	+ 55.2	1.1		
195068–9		5251	20 24.0	+49 3	5.7	F0s	.093	4	− 20.3	2.2		
195774		5271	20 28.2	+48 53	5.6	M2	.037	3	− 62.2	1.5	−66.0	V
196124	Cin.	2668	20 30.2	+ 5 47	8.7	K5	.44	4	− 32	1		
196180	Boss	5282	20 30.6	+14 20	4.7	A2	.038	3	− 28	2	−24	L
196758		5305	20 34.3	+ 0 8	5.4	G8	.094	3	− 45.4	1.9	−41.8	L
196852		5309	20 34.9	+29 59	5.9	G7	.090	3	+ 13.2	1.1	+12.4	V
196882	βG.C.	10404Br	20 35.1	+21 22	8.2	K3	....	5	−111	3		
196892	Cin.	2680	20 35.1	−19 8	8.6	F5	.440	4	− 30	3		
197684	βG.C.	10483Br	20 40.1	+11 57	6.7	A6n	....	3	− 11	2		
198542	Boss	5363	20 45.9	−27 18	4.2	M1	0.017	3	+ 4.5	±1.4	+11.4	L

									km/sec.	km/sec.	km/sec.	
199178	Boss	5380	20h 50m.4	+44° 0′	7.6	G4	0″.021	3	− 22.0	±1.0		
199345		5386	20 51.5	−10 5	5.7	K5	.021	3	− 33.1	1.6		
200004		5407	20 55.6	−13 55	6.6	G3	.005	3	+ 22.3	1.1		
....	Luyten	639	20 56.2	+39 41	9.7	M3e	.671	3	− 57	3		
200310	Boss	5414	20 57.7	+45 46	5.2	B3	.004	4	− 20	4	−20::	L
200497		5418Br	20 58.8	− 6 13	5.9	G2	.018	3	+ 0.6	1.0		
200914		5430	21 1.3	−25 24	4.6	M0	.059	6	+ 29.4	1.5	+32.4	L
200968	βG.C.	10727	21 1.6	−14 19	7.2	K0	.373	4	− 37.2	2.5		
201901	Boss	5448	21 7.4	−28 2	5.6	K5	.167	4	− 42.7	2.2		
201889	Cin.	2750	21 7.5	+23 45	8.0	F9	.460	3	−102.5	0.2		
202380	Boss	5458	21 10.2	+59 41	7.1	M2	.012	3	− 14.8	1.5		
202466		5462	21 10.9	− 9 38	6.8	M4	.012	3	+ 7.7	1.3		
202751	Cin.	2763	21 12.9	− 0 15	8.5	K6	.476	5	− 28	2		
203040		2770	21 14.6	−20 15	9.2	K6	.764	3	+ 21	1		
203291	Boss	5479	21 16.1	+ 6 56	6.0	M3	.044	3	− 22.8	0.6	−18.8	V
203475		5487	21 17.3	−23 6	5.7	M0	.041	3	− 7.3	2.4		
203925		5504	21 20.1	+25 45	5.7	F1s	.039	3	+ 3.0	0.9	− 6.8	V
204129Br		5508Pr	21 21.5	+79 55	8.1	F5s	.185	3	+ 28	2		
204139		5510	21 21.6	−21 38	6.0	K5	.037	3	+ 23.0	2.5		
204381		5513	21 23.0	−22 15	4.6	G5	.132	3	− 27.2	2.1	−22.0	L
205021Ft		5532Ft	21 27.4	+70 7	8.0	A3n	.012	4	− 18	3		
205114–5	B.D.+51°	3079	21 28.1	+52 11	6.2	K0	....	3	− 26.3	0.2		
205855	Cin.	2808	21 33.0	− 2 45	8.8	K5	.566	3	+ 7	2		
206330	Boss	5567	21 36.3	+42 49	5.4	M1	.054	4	− 26.8	0.8	−27.7	L, V
206487		5572	21 37.3	+ 5 13	5.6	M2	.022	4	− 4.0	1.1		
206827		5588	21 39.7	+28 17	6.1	F8	.370	3	+ 16.5	1.1		
207491	Cin.	2833	21 44.1	+ 5 15	8.6	K6	.54	3	− 11	0		
207862Br	βG.C.	11302Br	21 46.9	+ 8 37	7.9	A8	....	3	+ 17	4		
208057	Boss	5627	21 48.5	+25 27	5.0	B3	.001	2	− 16	4	−21:	L
208063		5628	21 48.6	+55 19	7.3	A1s	0.045	4	− 6	±2		

TABLE I—*Continued*

H.D.	Star	α 1900	δ 1900	m	Sp.	μ	No.	v	P.E.	Other Determinations v	Other Determinations Auth.
								km/sec.	km/sec.	km/sec.	
208074	B.D. +66° 1446	$21^h48^m.7$	+66° 22′	8.3	F4s	0″.014	6	− 16	±2		
....	Luyten 680	21 50.8	+32 10	10.8	G1	.73	3	−178	0		
208552Br.	βG.C. 11372Br	21 51.9	+15 41	8.3	F5	.039	3	− 21.9	0.6		
208742	Boss 5647	21 53.3	+79 5	6.8	M2	.029	3	− 15.8	1.6		
209761	5673	22 0.6	+26 11	5.9	K0	.048	4	− 21.0	1.5	−27.8	V
209772	5678	22 0.9	+62 38	5.5	M5	.052	3	− 3.8	0.8	− 3.7	L, V
209960	5685	22 2.0	+62 18	5.4	K5	.065	2	− 21.2	1.9	−20.9	L
209945	5686	22 2.0	+44 32	5.3	M0	.017	3	− 20.3	0.8	−23.8	L
210277	5697	22 4.2	− 8 2	6.6	G0	.458	4	− 23.6	1.4		
210302	5698	22 4.3	−33 2	5.1	F6	.447	3	− 14.2	0.5	−14.7	L
210354	5701	22 4.8	+32 41	5.6	G6	.092	3	− 6.2	1.8	− 4.7	V
210464	5708	22 5.5	−21 43	6.1	F6	.111	3	− 13.2	1.9		
....	Cin. 2889	22 5.9	+22 19	8.8	K3	.592	4	− 25	4		
210918	Boss 5725	22 8.5	−41 51	6.4	G0	.955	3	− 18.9	2.2		
211076	5731	22 9.5	+16 42	6.6	K4	.132	7	− 35.8	1.2		
....	βG.C. 11614	22 11.4	+30 55	9.3	F4s	....	3	− 9	3		
211833	Boss 5756	22 14.9	+62 18	6.0	K2	.051	3	+ 0.4	0.8	− 4.5	V
212010	5759	22 16.1	−22 6	5.4	K2	.089	3	+ 47.1	0.9	+48.1	L
212005Br.	βG.C. 11657Br	22 16.1	+24 26	8.3	G6	.057	5	+ 2	1		
212391Br.	Boss 5771Br	22 18.8	+66 12	6.7	G5	.042	4	− 3.2	2.1	− 1.5	V
213013Br.	βG.C. 11741Br	22 23.4	+23 1	8.3	G7	....	3	− 19	1		
213013Ft.	11741Ft	22 23.4	+23 1	8.8	K2	....	3	− 23	3		
213119	Boss 5797	22 24.1	+ 8 37	5.8	M0	0.062	3	− 34.1	0.4	−29.3	V
....	B.D. +53° 2911	22 28.7	+53 16	9.5	M1	1.482	3	− 2	3		
213893	Boss 5820	22 29.5	+ 0 5	7.0	M1	0.089	4	− 88.7	±2.3		

								km/sec.	km/sec.	km/sec.	
214028	Boss 5825	22h 30m.4	−17° 59′	6.8	K5	0″.057	3	− 8.5	±1.0		
......	B.D.+60° 2412	22 31.4	+60 17	9.0	K5	......	3	− 1	1		
214605–6	+68° 1319	22 34.3	+68 41	7.5	F4	......	3	+ 12.0	1.6		
214665	Boss 5843	22 34.7	+56 17	5.5	M4	.056	3	+ 10.9	0.5	+ 6.9	L, V
214966	5855	22 36.8	−29 53	6.4	M5	.030	4	− 9.1	1.1		
214995	5857	22 37.0	+14 0	6.1	G9	.096	4	− 25.2	1.3		
215318–9	5866	22 39.2	+80 52	6.9	G0	.024	3	+ 10.2	0.3		
215324	βG.C. 11930	22 39.2	+45 30	7.4	F5	.174	3	− 32.7	1.3		
215373	Boss 5869	22 39.6	+41 18	5.2	G5	.011	3	+ 12.6	0.8	+13.5	L
......	βG.C. 11943	22 40.5	+10 40	8.5	K5	......	3	+ 5	1		
215578	11952	22 41.2	+18 48	7.5	G8	.034	3	− 20.2	0.9		
......	B.D.+43° 4305	22 42.5	+43 49	9.5	M5e	.86	3	+ 2	2		
216172p	βG.C. 11997p	22 45.6	+68 2	7.2	F5s	.126	3	+ 3.1	1.2		
216172f	11997f	22 45.6	+68 2	7.2	F4s	.126	3	+ 1.5	0.5		
216397	Boss 5897	22 47.5	+42 47	5.2	M0	.106	6	− 16.2	0.6	−17.5	L
216991	B.D.+79° 758	22 52.0	+79 43	7.8	G8	......	3	− 11.8	0.8		
217701	Boss 5934	22 57.4	− 7 7	6.5	M2	0.039	3	− 8.1	2.4		
217987	Cin. 3014	22 59.4	−36 26	7.4	M2	6.900	4	+ 7.8	2.1		
218029	Boss 5943	22 59.7	+66 40	5.5	K3	0.033	3	− 4.7	1.2	− 7.9	L
218347	Cin. 3023	23 2.2	+15 44	9.3	F7	.170	3	− 22	1		
218452	Boss 5957	23 3.1	+45 51	5.6	K5	.030	3	− 6.6	0.9		
218739	βG.C. 12200Br	23 5.3	+47 26	7.0	G2	......	4	− 8.4	1.4		
218792	Boss 5971	23 5.7	+17 3	5.9	K4	.033	3	+ 0.6	0.9		
219127	βG.C. 12229Br	23 8.3	+39 28	7.4	A7n	.084	3	0	2		
219449	Boss 5981BC	23 10.7	− 9 38	9.0	K6	.367	4	− 26	2		
219576	5986	23 11.7	− 8 16	5.1	M5	.022	3	− 17.8	2.0	−14.8	L
219981	6003	23 15.1	+41 32	6.0	M0	.044	3	+ 3.1	2.3		
220009	6004	23 15.2	+ 4 50	5.2	G9	.100	3	+ 35.0	0.5	+39.7	L
220117	6008	23 16.1	+37 38	5.8	F4s	.139	3	− 10.0	1.9	− 9.1	V
220149Br	βG.C. 12317Br	23 16.4	+34 53	8.5	G9	0.023	4	+ 6	±1.5		

TABLE I—*Continued*

H.D.	Star	α 1900	δ 1900	m	Sp.	μ	No.	v	P.E.	Other Determinations v	Other Determinations Auth.
								km/sec.	km/sec.	km/sec.	
220149Ft	βG.C. 12317Ft	23h16m.4	+34° 53′	9.0	K2	......	4	− 35	±3		
220436	Boss 6017Br	23 18.6	− 9 1	7.0	G6	0″.016	3	− 8.0	0.9		
220636–7	B.D.+76° 915	23 20.3	+76 58	7.9	F6	......	3	− 21.5	1.6		
220704	Boss 6026	23 20.8	−21 11	4.5	K5	.083	3	+ 13.0	1.3	+15.4	L
221615	6058	23 28.5	+21 57	5.5	M5	.036	3	+ 2.0	1.1	+ 2.1	V
221673	6059	23 29.0	+30 46	5.2	K4	.053	2	− 22.7	2.4	−24.2	L
221950	6067	23 31.3	+ 1 33	5.6	F2n	.125	4	+ 39.4	1.5		
222493	6081	23 36.0	−12 14	6.1	G7	.062	4	− 10.1	1.6		
222641	6086	23 37.3	+44 26	6.7	K5	.024	3	− 11.6	1.9		
222683	6088	23 37.7	+15 47	6.5	G7	.084	3	− 1.2	0.5		
222766	B.D.−8° 6177	23 38.3	− 8 27	9.7	G2	.64	3	− 98	2		
223047	Boss 6101	23 41.1	+45 52	5.1	K0p	.022	3	− 26.3	0.3	−24.5	L
223552	6117	23 45.4	+51 4	6.5	A9	.123	3	− 22	1		
223637	6121	23 46.2	+ 8 46	6.1	M2	.063	3	− 7.8	1.0	− 9.7	V
223718p	βG.C. 12601p	23 46.8	+37 21	7.0	F5s	......	3	− 19.9	2.0		
223718f	12601f	23 46.8	+37 21	7.0	F5s	......	3	− 17.8	2.5		
224062	Boss 6137	23 49.7	− 0 27	6.0	M5	.057	3	− 2.7	0.8		
224225	6143	23 51.0	−22 33	7.4	M2	.050	3	− 5.2	1.5		
224618	B.D.−17° 6856	23 54.2	−17 30	8.5	G5	......	3	− 44	2		
224758	Boss 6162	23 55.3	+26 22	6.4	F5s	.064	5	0.0	1.2		
224873	βG.C. 12696m	23 56.3	+39 4	8.6	K1	......	3	0	1		
224995	Boss 6174	23 57.3	+ 8 24	6.3	A3n	.004	7	+ 14	2		
225216	6184	23 59.5	+66 37	5.8	G8	0.102	3	− 26.6	0.3		
225213	Cin. 3161	23 59.5	−37 51	8.3	M3	6.112	4	+ 23	3		
225291Br	βG.C. 12736Br	23 59.8	+45 7	7.9	F8	0.031	4	− 17.5	1.4		
6	Boss 6188	23 59.9	− 1 3	6.3	G8	0.061	3	+ 14.2	±0.8		

in each spectral type based on our own classification is as follows: O, 1; B, 19; A, 71; F, 132; G, 193; K, 189; M, 136; total, 741.

A large proportion of the fainter stars are dwarfs with large proper motions. They were photographed with the 10-inch camera. The radial velocities of all such stars have been rounded off to even kilometers. The same procedure has been followed for stars of types B and A, observed with the 18-inch camera; but for other types the fractional part of the kilometer has been retained.

Soon after the publication of the *Catalogue of Stellar Radial Velocities* by the Lick Observatory a comparison was made between the results for all stars observed in common at the Lick and Mount Wilson observatories. The systematic differences and average deviations for a single star in a total of 534 stars are as follows:

Type	No.	Mt. W.-Lick	Aver. Dev.
		km/sec.	km/sec.
B..........	86	+0.51	4.9 (Good lines, 2.4)
A..........	81	− .24	3.7 (Good lines, 3.0)
F..........	73	− .52	2.08
G..........	74	− .05	1.85
K..........	162	+ .91	2.01
M..........	58	+0.84	2.04

The greater dispersion used for the Lick spectrograms and the high order of accuracy attained in their measurement have led us to apply these values as corrections to the results derived from the low-dispersion Mount Wilson spectrograms for all stars of advanced spectral type. The differences are especially significant in types K and M, where they seem to be due mainly to the wave-lengths of some of the blended lines used on the plates of smaller scale. In the present list no correction has been applied to stars of types B and A, but for the remaining types the following values have been used throughout: F, +0.5; G, 0.0; K, −0.9; M, −0.8.

Our list contains 142 stars in common with the Lick Observatory *Catalogue*, some of which were used in the previous comparison, but many of which are new. There are also 96 stars in common with published lists from the Dominion Astrophysical Observatory at Victoria. The results of a comparison with these stars are shown in the table on page 236.

The average deviation for a single star for types F–M is 2.2 km/sec. when compared with the Lick values, and 2.3 km/sec. when compared with Victoria. In a few cases, especially among stars of type F, the size of the differences suggests the probability of variable velocity, but all values have been included in the comparison.

An interesting feature of the results, but one which would naturally be expected in a list containing so many stars of large proper motion, is the exceptional number of stars with high radial velocities. Corrected for the solar motion, twenty-six velocities exceed 70 km/sec., and seven exceed 100 km/sec. Two of the latter are for stars previously observed by Luyten. No exact count has been made of the number of velocities greater than 50 km/sec., but there are

Type	No.	Mt. W.–Lick	Type	No.	Mt. W.–Victoria
		km/sec.			km/sec.
B..........	15	+1.2	A..........	8	−0.6
A..........	20	−0.7	F..........	17	+1.6
F..........	12	+ .7	G..........	30	+0.3
G..........	28	− .7	K..........	26	+1.1
K..........	36	+ .5	M..........	15	+0.8
M..........	31	+0.1			

at least seventy. These stars show in a very marked way the asymmetry of stellar motions studied by Strömberg, the result being an almost complete absence of stars of large positive velocity in the northern sky between fifteen hours and two hours of right ascension.

Six stars, two of which are fainter than the ninth magnitude, are shown by the radial velocities and proper motions to be members of the Taurus group. The mean value of their radial velocities is +39.1 km/sec. The faintest star photographically in the entire list is the distant companion of Capella, a dwarf star of type M2. In view of the low dispersion employed, its radial velocity, +36 km/sec., is in satisfactory agreement with the motion of the principal star, +30.2 km/sec. The components of seven Struve double stars show considerable disagreement in radial velocity. As they are mostly wide pairs it is probable that they are optical doubles. They appear in the *Catalogue* as βG.C. 3319, 4062, 6064, 7212, 12317, Boss 4101–2 and 4340–1.

Carnegie Institution of Washington
Mount Wilson Observatory
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THE STARK EFFECT AS A MEANS OF DETERMINING COMPARATIVE ABSOLUTE MAGNITUDES

By OTTO STRUVE

ABSTRACT

The ratio of *intensity of the forbidden helium line* λ 4470 to that of the permitted line λ 4472 *is used for* the determination of relative *absolute magnitudes* of B-type stars. The total *range of absolute magnitude* within a single spectral subdivision *is* of the order of *3 mag.* The star 67 Ophiuchi, of type B5p, is found to be highly luminous; its absolute magnitude is 3.0 mag. brighter than that of 88 γ Pegasi, of type B2, and its distance is estimated at 600 parsecs. This is verified by the fact that *67 Ophiuchi has a fairly strong interstellar line of* Ca^+.

There are four distinct criteria for determining the intensity of the mol-electric Stark effect in stellar spectra: (1) the intensity of forbidden lines of helium; (2) the widths of the Balmer lines of hydrogen; (3) the difference in haziness between members of the series ($2P-mD$) and members of other series, in parhelium as well as in orthohelium; (4) the amount of shift in wave-length caused by the unsymmetrical widening of certain helium lines.

In my former papers[1] I have shown that all four criteria give reasonable results, and that the observed phenomena lead to an average pressure of 10^{-4} atmospheres in the reversing layers of the stars. Criteria (2)–(4) are complicated by the effect of broadening caused by the number of active atoms present, and consequently involve the theory of ionization. The present paper will be limited to a discussion of the intensities of forbidden helium lines. Broadening due to axial rotation has been eliminated by using only those stars in which the lines of the heavier elements appear perfectly sharp and narrow.

If F designates the electric force at a distance x from a free electron (or single positive charge) we have

$$F=\frac{e}{x^2}\,.$$

[1] *Astrophysical Journal*, **69**, 173, 1929; **70**, 85, 1929; see also C. T. Elvey, *ibid.*, **69**, 237, 1929; **70**, 141, 1929; J. Pauwen, *ibid.*, p. 263, 1929.

If there are n charges per cubic centimeter, we have approximately

$$x=c\cdot n^{-\frac{1}{3}}$$

so that

$$F=c\cdot e\cdot n^{\frac{2}{3}}\ .$$

Boyle's law for perfect gases gives

$$n\propto\frac{P}{T}\ ,$$

where P is the total pressure of the gas. Let us assume that $P\propto p'$, where p' is the partial pressure of the free electrons. Then

$$F=\text{const.}\ e\cdot\left(\frac{p'}{T}\right)^{\frac{2}{3}}\ .$$

We can now express p' as a function of the temperature T and of g, the acceleration of gravity at the surface of the star. According to E. A. Milne,[1]

$$p'\propto\frac{g^{\frac{1}{2}}}{T^2}\ .$$

Consequently,

$$F=\text{const.}\ e\cdot\frac{g^{\frac{1}{3}}}{T^2}\ .$$

The quantity g can be expressed in terms of absolute magnitude and temperature by the following substitutions:[2]

$$g=\frac{\gamma\cdot\mu}{R^2}\ ,$$

$$\log\mu=-0.133M+0.645\ ,$$

$$\log R=-0.2M-2\log T+8.53\ ,$$

where μ = mass of the star, R = radius of the star, M = absolute bolometric magnitude. We obtain[3]

$$\log F=+0.1M-0.67\log T+\text{const.}$$

[1] *Monthly Notices of the Royal Astronomical Society*, **85**, 782, 1925.

[2] *Astrophysical Journal*, **70**, 102, 1929.

[3] Since the width of a line is approximately proportional to the field, $\log W=0.1M-0.67\log T+\text{const.}$ This formula should be substituted for the one used in *Astrophysical Journal*, **70**, 102, 1929, in which I have incorrectly omitted T. In the particular problem

If two stars have been observed in which the electric fields are F_1 and F_2 we find the difference in absolute magnitude

$$M_1 - M_2 = 10 \log \frac{F_1}{F_2} + 6.7 \log \frac{T_1}{T_2} .$$

Stellar spectra do not directly give the values of F_1 and F_2. The observed quantities are the intensities of the forbidden lines and of the permitted lines. Consider the two lines $(2^3p - 4^3f) = \lambda\,4470$ (forbidden) and $(2^3p - 4^3d) = \lambda\,4472$ (permitted). For emission lines in a constant electric field the following relationship has been derived theoretically and tested in the laboratory:[1]

$$\frac{I(2^3p - 4^3f)}{I(2^3p - 4^3d)} = A \cdot F^2 .$$

For the p-components, polarized parallel to the field, the constant A has the value[2] 6.6×10^{-10}, F being expressed in volts per centimeter. For the s-components A has a slightly different value.

It would probably not be correct to use the same constant for stellar absorption lines. The relative intensities may not be exactly preserved in absorption; furthermore, we are dealing here with a fluctuating effect. The effective value of F is an average of the

discussed there, the temperature cannot be omitted. The result will be a slightly smaller value for the change in maximum line-width. The conclusion that Stark effect will tend to produce a shift in the observed maximum of the wings of a line is, of course, unaltered.

Dr. P. W. Merrill has kindly called my attention to another oversight. The two lines mentioned at the top of p. 98 of my former article (*ibid.*) should be Si^{++} 3924 and *He* 3926, instead of 4024 and 4026.

[1] I am indebted to Professor Takamine and to C. T. Elvey for calling attention to this relationship and to the work of Miss Dewey (see next footnote).

[2] J. M. Dewey, *Physical Review*, **28**, 1108, 1926; **30**, 770, 1927. Attention may be called to a few numerical errors in Table II (p. 1120) of Miss Dewey's first paper. These are easily corrected by means of her actual intensities. It is somewhat disconcerting to find that for the same lines T. Takamine and S. Werner (*Die Naturwissenschaften*, **14**, 47, 1926) find a ratio:

$$\frac{I(4470)}{I(4472)} = 0.3 ,$$

for $F = 13{,}200$ volt/cm. Miss Dewey finds much smaller values, and explains the discordance by the small resolving-power of the spectrograph used by Takamine and Werner. An important paper on the Stark effect and series limits by H. P. Robertson and J. M. Dewey appeared in *Physical Review*, **31**, 973, 1928.

squares of the individual molecular fields, and not the arithmetical mean of the F's. It does seem permissible, however, in the absence of more accurate laboratory data on the intensities of absorption lines affected by molecular Stark broadening, to preserve the relation

$$\frac{I(4470)}{I(4472)} \propto F^2 .$$

This leads directly to the following expression:

$$M_1 - M_2 = 5 \log \frac{i_1}{i_2} + 6.7 \log \frac{T_1}{T_2} ,$$

where

$$i = \frac{I(4470)}{I(4472)} .$$

If we limit ourselves to stars of a single spectral subdivision we may put

$$T_1 = T_2$$

so that

$$M_1 - M_2 = 5 \log \frac{i_1}{i_2} .$$

For the intensities of the lines we use total absorbed energies. If the contour of a line is given as a function of the wave-length, $I(\lambda)$, we have

$$i = \frac{\int I(\lambda)_{4470}\, d\lambda}{\int I(\lambda)_{4472}\, d\lambda} .$$

The integration was performed graphically for the star 88 γ Pegasi (B2) on the contours determined by J. Pauwen.[1] The result is

$$i_1 = 0.19 .$$

This is the largest value of i thus far found for any star. In many other stars the forbidden line at λ 4470 is so faint that the photometric method becomes quite unreliable. The star 67 Ophiuchi (B5p) shows a bare trace of λ 4470 on the best plates. A rough estimate leads to

$$i_2 = 0.05$$

[1] *Astrophysical Journal*, **70**, 263, 1929.

so that

$$\frac{i_1}{i_2}=4\ .$$

Substituting this in our equation, we find

$$M_1-M_2=5\log 4=3.0\ \text{mag.}$$

The star 67 Ophiuchi is by 3.0 mag. more luminous than 88 γ Pegasi, in spite of the fact that its spectral type is B5p while that of γ Pegasi is B2. Adopting for γ Pegasi the visual absolute magnitude -2.0, we find the following distances for the two stars:

Star	Sp.	Vis. Mag.	Abs. Mag.	Distance in Parsecs
γ Pegasi	B2	2.9	(−2.0)	100
67 Ophiuchi	B5p	3.9	−5.0	600

The great distance of 67 Ophiuchi can be checked by means of the calcium line K. At 600 parsecs we may expect a fairly strong interstellar line having an intensity of three units or more, on my arbitrary scale.[1] The average B5 star has a weak stellar line of calcium of intensity 2 or less.[2] Consequently the interstellar line should predominate in the spectrum of 67 Ophiuchi. I have verified this from measures of the radial velocity (Table I). I have also checked the spectral type of 67 Ophiuchi and found it to be B5. The Harvard and Mount Wilson criteria make it definitely later than B3. So far as is known to me, this is the first B5 star found to have interstellar calcium lines.

TABLE I

RADIAL VELOCITY OF 67 OPHIUCHI

Date	Vel.—Star	Vel.—*Ca.*+	Measurer
1903 Oct. 17.540 G.M.T.	+2.2 km/sec.	−12.1 km/sec.	O. J. Lee
1906 Apr. 27.885 G.M.T.	+0.3	− 7.4	O. J. Lee
1929 July 19.246 U.T.	−1.4	− 7.9	Struve
1929 July 27.174 U.T.	−0.6	−12.7	Struve
Mean	−1.0	−10.0	

[1] *Monthly Notices of the Royal Astronomical Society*, **89**, 570, 1929 (Fig. 1).

[2] *Astrophysical Journal*, **67**, 379, 1928 (Fig. 3).

The large value of $(M_1 - M_2)$ found above suggests that there is a considerable dispersion in absolute magnitudes among the B stars. The total range may even exceed the value of 3.0 mag. This is in good agreement with my former results from star-counts[1] and from the interstellar calcium lines.[2] It is further supported by the statistical investigations of A. Pannekoek.[3]

It was not possible to extend the investigation to other forbidden lines. The laboratory data of J. M. Dewey[4] show that most other forbidden lines of helium in the photographic region of the spectrum are very faint. On our plates the companion to λ 4388 is not well separated from the permitted lines; λ 4922 is usually not in the best focus, and for λ 4026 the resolution is too complicated; λ 4519 and λ 4047 as well as λ 4911 are far too faint for all practical purposes.[5] I have made an attempt to observe the forbidden lines at λ 6632 and at λ 6069, noted by T. Suga.[6] The first line lies in a region where the sensitivity of the plate falls off rather rapidly, and very long exposures would be required to photograph it with sufficient dispersion. On a plate of 88 γ Pegasi, λ 6069 cannot definitely be seen. This may be due to the lack of contrast of the photographic plate, but it seems more probable, from Suga's curves, that the line is too faint for our equipment.

YERKES OBSERVATORY
November 8, 1929

[1] *Astronomische Nachrichten*, **231**, 17, 1927.

[2] *Monthly Notices of the Royal Astronomical Society*, **89**, 567, 1929.

[3] *Publications of the Astronomical Institute of the University of Amsterdam*, No. 2, 1929.

[4] *Op. cit.*

[5] *Astrophysical Journal*, **70**, 91, 1929.

[6] *Ibid.*, **70**, 201, 1929.

THE ABSORPTION BAND RECORDED IN STELLAR SPECTRA AT λ 4200

By C. T. ELVEY and R. S. ZUG

ABSTRACT

The *absorption band* at λ 4200 in the plates of four stars made with the Bruce spectrograph attached to the 40-inch refractor of the Yerkes Observatory is about 120 A wide and centered near λ 4195. The *central depth* of the band is 9 per cent absorption of the continuous spectrum.

Observations were made of the amount of *selective absorption in the glass* of the optical system and they *fully account for the stellar band*. The *contours* of the bands were determined.

The *crown lens of the 40-inch objective exhibits* the weak absorption band at λ 4345.

It is *suggested* that a *part of the absorption bands* near λ 3800 in stellar spectra *also might be due to the glass*.

The wide absorption band photographed in stellar spectra approximately at wave-length λ 4200 has been recorded by a number of observers. Perhaps the first notice of the band is that of H. Shapley[1] in 1924. He finds in the spectrum of Vega an absorption band about 80 A wide between $H\gamma$ and $H\delta$. The average loss of light from the continuous spectrum is a little over 2 per cent and the maximum loss, which is near λ 4160, is 3.5 per cent. He attributed the absorption to the cyanogen band at λ 4215 which has been identified in the spectra of stars of late type. In 1928 Shapley[2] again discussed this absorption band in the spectra of one hundred stars In some of the spectra the band is missing, while in others it is quite strong. It occurs apparently in all spectral classes. In the nebulous region of the Pleiades the intensity of the band is much higher than the average. The limits of the band vary through a considerable range. The average value of the limit for the violet side is λ 4150 and for the red side λ 4244. If the band is symmetrical the center would be at λ 4197. However, in his summary Shapley gives the center as being near λ 4180. Also, in the summary he says, "The variety in its strength and limits, even for closely adjacent stars photographed on the same plate, shows that it is real and not instrumental."

[1] *Harvard Bulletin*, No. 805, 1924.

[2] *Ibid.*, Nos. 856, 857, 1928.

Shortly after the foregoing articles of Shapley appeared W. J. S. Lockyer[1] presented a communication which he summarizes as follows:

(1) The spectra of many B-type stars photographed at the Norman Lockyer Observatory at Sidmouth display a strong absorption band between the limits λ 4170 and λ 4250 approximately. (2) The presence of this band cannot be explained as due either to the absence of bright lines in that region [this was an explanation given by Lockyer in an earlier paper (*Monthly Notices*, **86**, 496, 1926)] or to local absorption caused by the optical parts of the instrument used. (3) Reference is made to Dr. Shapley's investigation of the presence of this band in stars of all spectral classes and to his suggested origin as due to cyanogen.

At the Amherst Meeting of the American Astronomical Society Mrs. Laura Hill McLaughlin[2] reported on the bands between $H\gamma$ and $H\delta$ in early type stars. From a study of some two hundred microphotometric tracings of spectrograms of γ Lyrae and β Lyrae she obtains bands which have centers at λ 4310, λ 4275, and λ 4215. She says, "Estimates of intensity are valueless, due to differences in density of the individual spectrograms; actual measures are almost valueless, due to the extreme faintness of the bands." The bands are attributed to absorptions in the upper atmosphere. Intense absorption bands in the spectra of β Lyrae and P Cygni on the same night are correlated by her with a strong aurora on that night. On the plate of β Lyrae the greatest absorption is between λ 4220 and $H\delta$; and on the plate of P Cygni the greatest absorption is between $H\gamma$ and λ 4175.

Miss Carol Anger[3] records on plates made with the slit spectrograph of the Dearborn Observatory an absorption band of variable intensity which extends from approximately λ 4178 to λ 4210 in the spectrum of α^2 Canum Venaticorum. Also, Miss A. V. Douglas presented at the Ottawa Meeting of the American Astronomical Society, September, 1929, a paper entitled "Anomalous Behavior of Cyanogen in Three Variable Stars." She records a correlation of the variation of the intensity of the band λ 4200 with the periods of some Cepheid variables.

Shapley[4] in December, 1928, withdraws his identification of the

[1] *Monthly Notices*, **89**, 127, 1928.

[2] *Popular Astronomy*, **36**, 601, 1928.

[3] *Astrophysical Journal*, **70**, 117, 1929.

[4] *Op. cit.*, No. 862, 1928.

band at λ 4200 with the cyanogen band at λ 4215. With the assistance of Professor E. S. King he has shown that a large part of the absorption band is due to the glass of the optical system. He calls attention to some measurements of the transmissions of the optical glasses of the refractor of the Potsdam Astrophysical Observatory by Müller and Wilsing in which they show an absorption band at λ 4186. We may quote from Everett's translation of Hovestadt's *Jena Glasses* (p. 48):

> Further, it was found that a plate about 15 cm. thick of flint O 340 produced two absorption bands; one faint and diffused, having its centre at 0.437 μ, the other conspicuous, with sharply defined edges, at 0.4186 μ. The breadth of the latter corresponded to a difference of wave-length 0.0035 μ. The latter band also showed itself, but not so strongly, with a plate of crown O 203 about 14 cm. thick. The heavy flint O 102 showed no absorption band.

A. Pannekoek and M. G. J. Minnaert[1] in their photometric study of the flash spectrum of the solar eclipse of June 29, 1927, have determined the apparent intensities in the continuous spectrum of a standard lamp through the spectrograph used at the eclipse. The curve of intensities shows a minimum near λ 4200 which they identify as selective absorption in the optical glass. There is another minimum at λ 4400 which is certainly real, but they have not identified it.

In view of the observations showing the presence of an absorption band in optical glass at about the same wave-length as the band observed in stellar spectra, we have attempted to make a quantitative determination of the amount of the selective absorption in the optical system of the Bruce spectrograph attached to the 40-inch refractor of the Yerkes Observatory.

Perhaps at this point it will be well to recall the dimensions of the optical parts of the equipment. The crown lens of the 40-inch objective is 19 mm thick at the edge and 60 mm thick at the center. The flint lens is 51 mm thick at the edge and about 32 mm at the center. The correcting lens, designed by F. E. Ross, is composed of two elements, a flint lens of axial thickness of 12 mm, and a crown lens which has a thickness of 10 mm. In the spectrograph the collimating lens is a quadruple isokumatic by Hastings. We do not know

[1] *Verhandlingen der Koninklijke Akademie van Wetenschappen te Amsterdam, Afdeeling Natuurkunde* (eerste sectie), **13**, No. 5, p. 24, 1928.

the thickness of this lens system. The prism is of Jena glass No. O 102, and the average thickness is 90 mm. The camera lens is a quadruple designed by Ross. The axial thickness of the crown glass is 11.2 mm and of the flint 5.2 mm.

First we took standardized spectrograms of several stars and analyzed them with the registering microphotometer to determine the extent and depth of the absorption bands in their spectra. Within the errors of observation the bands in the various spectra are of the same shape and size. The band is about 120 A wide with its center near λ 4195. This agrees well with the mean of the limits given by Shapley for the band. The central intensities of the bands, expressed in stellar magnitude by which the continuous spectrum is decreased and in percentages of absorption of the continuous spectrum, are: 17 Leporis, 0.13 mag. or 11 per cent; 27 Canis Majoris, 0.10 mag. or 9 per cent; 50 α Cygni, 0.10 and 0.09 mag. or 9 and 8 per cent; and α Canis Majoris, 0.09 mag. or 8 per cent. The two spectrograms of α Cygni were taken as similarly as possible in order that they might be used for a comparison of two developers. The contrasts of the two spectrograms are very different, but the results are in good agreement. The plate of α Canis Majoris was taken with a large extra-focal image of the star on the slit of the spectrograph so that any effects of atmospheric dispersion, or the secondary spectrum of the refractor and the correcting lens, would be eliminated.

The mean contour for the absorption band in stellar spectra is shown in Figure 1*a*.

To obtain an idea of the amount of the selective absorption that is due to the glass of the optical system we have taken spectrograms of artificial sources of light which have a continuous spectrum. A projection lantern was mounted on the inside of the dome so that a beam of light could be projected down the telescope. A strong absorption band was found in the spectrum. The center of the band was very near λ 4200 and its width was about 135 A. The loss of light at the center of the band was 0.18 mag., which corresponds to 16 per cent absorption of the continuous spectrum. Observations were made with the use of the spectrograph and the projection lantern only. The result is a similar band, but of less intensity. The

loss of light was 0.09 mag. or 8 per cent absorption. Taking the difference of the two losses expressed in magnitudes, we have the loss due to the 40-inch objective and the correcting lens. This amounts to 0.09 mag. or 8 per cent.

Since there is a large amount of glass in the lenses of the projection lantern we repeated the experiment with the use of a 500-watt Mazda lamp for the source of light. The results in this case were a loss of 0.21 mag. or 18 per cent in the entire optical system and 0.11 mag. or 10 per cent in the spectrograph. This leaves a net loss of 0.10 mag. or 9 per cent absorption of the continuous spectrum at λ 4200 for the 40-inch objective and the correcting lens.

A spectrogram of a 100-watt Mazda lamp was also taken with the spectrograph, but not through the telescope as the exposure was rather long. The result was 6 per cent absorption of the continuous spectrum.

The contours of the absorption bands are similar. The mean of the absorption of the entire optical system has been plotted in Figure 1*b*, and the mean for the absorption in the spectrograph in Figure 1*c*.

For a short interval the spectrograph was converted into a two-prism instrument, the only change in the optical system being the addition of another prism. Observations of the absorption band were taken through the entire optical system which gave a loss of light of 0.19 mag. This is in good agreement with that obtained with the single-prism spectrograph and indicates that the addition of another prism did not increase the amount of absorption. The prisms are of dense flint glass O 102. Müller and Wilsing, as noted above, did not find any absorption bands in this type of glass.

The observed loss of light at λ 4200 in the 40-inch objective and the correcting lens agrees with that found for the stellar observations, but does not allow for any loss in the spectrograph. Since the three different sources give about the same results for the absorption in the spectrograph and since it seems rather improbable that all of the loss is in the glass of the lamp bulb, we expect that part of the absorption is in the instrument. Then the loss obtained from the spectra of artificial sources would seem to be greater than from the spectra of stars. However, if the greater part of the selective

absorption is in the crown glasses of the optical system there is no disagreement, for the light from the lamps traverses only the centers of the lenses of the telescope.

To test if the central parts of the lenses produce greater absorption than the peripheral zone, we obtained spectrograms of Vega with the 40-inch objective diaphragmed to an aperature of 10 inches, and others with the light coming through the outside 5 inches of the objective. The resulting losses on two spectrograms taken through the central zone of the optical system were the same, 0.13 mag. or 12 per cent absorption. The spectrograms through the outer zone gave losses of 0.05 mag. or 5 per cent absorption each. This shows that a large part of the absorption is in the crown glasses of the telescope and spectrograph. The contours are shown in Figures 1*d* and 1*e*.

We were able to obtain some measures of the amount of the selective absorption in the crown lens of the 40-inch objective by placing a mirror between the two elements of the objective to reflect a beam of light from a 100-watt lamp back through the glass and into the spectrograph. The mirror was silvered on the front surface. Control plates were taken with the use of the same mirror, and in each case precautions were taken to insure full illumination of the collimating lens. The results from the double thickness of the 40-inch crown lens are 0.11, 0.11, and 0.15 mag. loss of light at λ 4200 or 10, 10, and 13 per cent absorption of the continuous spectrum. The control plates gave losses of 0.05, 0.06, and 0.05 mag. or 5, 6, and 5 per cent. The mean contours are shown in Figure 1*f* and 1*g*.

The spectrograms taken through the double thickness of the crown lens show another absorption band which is not present in the control plates. This band has a center near λ 4345 and has a width of about 115 A. The loss of light in the center of the band is 0.05, 0.06, and 0.05 mag. or 5, 6, and 5 per cent absorption. The mean contour is shown in Figure 1*h*.

This absorption band is probably the same one found by Müller and Wilsing (*loc. cit.*) at λ 4370 in flint glass O 340. Also, a depression in the transmission curve for Bausch and Lomb mirror glass as given by Gibson, Tyndall, and McNicholas[1] may be due to the same

[1] *Bureau of Standards Technological Papers*, No. 148, p. 8, 1920.

selective absorption. That band, however, is of much greater extent. Their transmission curves for this mirror glass show a very

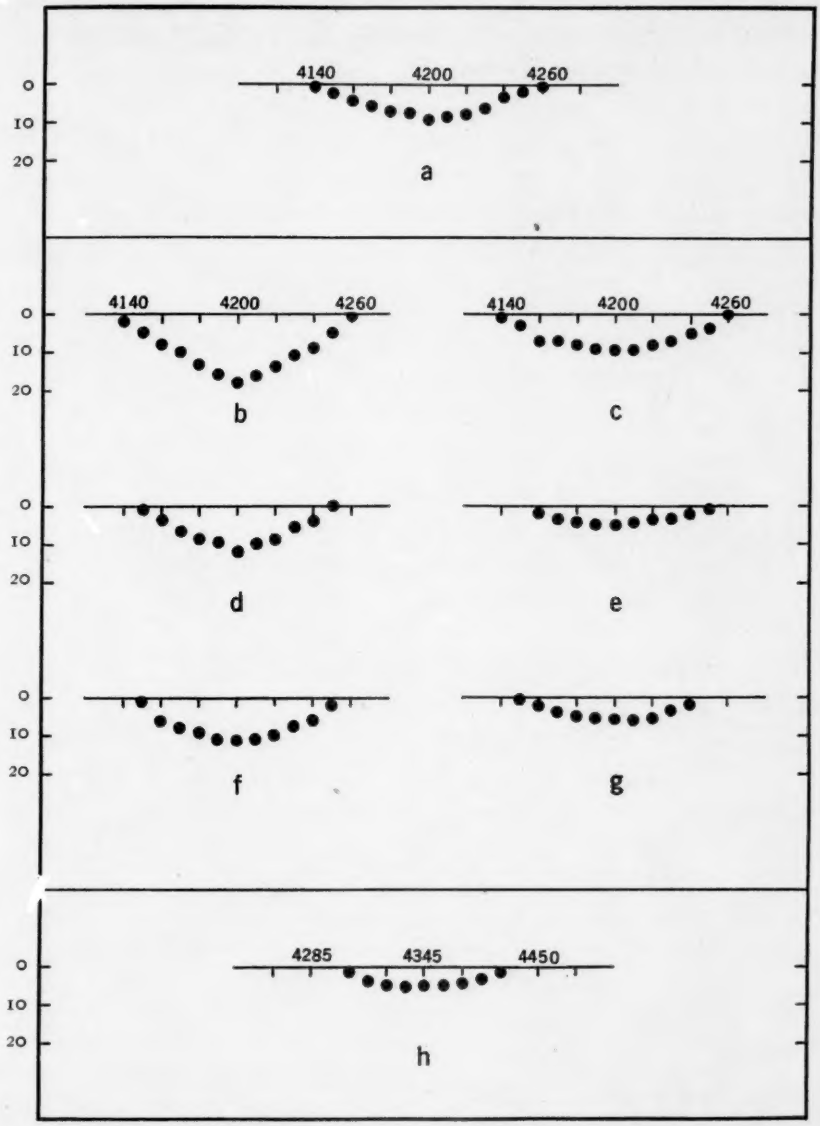

FIG. 1.—Mean contours of absorption bands in spectra as described in the test. The abscissae are wave-lengths, and the ordinates are intensities, expressed as percentages of absorption of the continuous spectrum.

marked depression at about λ 3800. If this band should exist in any of the optical glasses it will cause some difficulties in the measuring of the cyanogen band at λ 3885 in stellar spectra. The transmission curve given for several optical glasses of Jena by H. A. Krüs[1] do not have observed points close enough to show an absorption band of 100 A in width. The observations of Müller and Wilsing of the transmissions of the optical glasses in the refractor of the Potsdam Astrophysical Observatory were made by photographing the violet region with a spectrograph. Had there been any marked absorption bands in this region in those glasses they would no doubt have been found. However, since the cyanogen band at λ 3885 has such an important part in astrophysical problems, an investigation in this spectral region of any selective absorption of the optical glasses of the telescopes used in measuring the cyanogen absorption in stellar spectra would be in order.

Perhaps this selective absorption in mirror glass is the same as the pseudo-band at λ 3800 found by Shapley and Payne[2] in the spectra of certain early type stars. They attributed the band to a confluence of a number of strong, low-excitation lines of iron and magnesium which resulted from a bombardment of the star by meteors.

In the foregoing observations the absorption band at λ 4200 in stellar spectra is accounted for by the selective absorption of the glasses of our telescope and spectrograph. Most of the recorded observations of this band in stellar spectra indicate that it is of variable intensity, which would put the origin of the band outside of the instrument. However, the only quantitative observations are those for the band in Vega given by Shapley in his first paper. In view of the selective absorption of optical glass, accurate photometric observations must be made on the bands in the stellar spectra and in continuous spectra obtained with the same instrument in order to determine if there is a band of stellar or atmospheric origin.

YERKES OBSERVATORY
November, 9, 1929

[1] *Zeitschrift für Instrumentenkunde*, **23**, 197, 229, 1903.

[2] *Harvard College Observatory Circular*, No. 317, 1928.

THE CONTOURS OF SOME IRON LINES IN THE SPECTRUM OF 27 γ CASSIOPEIAE

By C. D. HIGGS

ABSTRACT

Some recent spectrograms of this well-known star of spectral class Be, taken at the Yerkes Observatory, clearly show the *similarity in structure* between the lines of *ionized iron* and of *hydrogen*. Emphasis is laid on this resemblance only, and no claim is made for individual features in the contours, factors involved in which are briefly mentioned.

Recent spectrograms of 27 γ Cassiopeiae taken at the Yerkes Observatory so well confirm previous observations with respect to the behavior of the iron lines in its spectrum that perhaps a brief preliminary announcement may not be out of place at this time. R. H. Curtiss first notes, in 1916, that the metallic emission lines share the well-known structure of the hydrogen lines in this star,[1] and later Merrill, Humason, and Miss Burwell,[2] and Merrill, again, in his discussion of stars whose spectra contain bright iron lines,[3] bear out their recognition and identification. The need for spectrograms of high dispersion with a maximum of contrast is stated as a prerequisite for further inquiry into the conditions obtaining in this stellar type.

The spectrogram selected for this particular cursory investigation was a three-hour exposure on an Eastman Process plate (No. R-1616), on October 8, 1929, at 1^h30^m U.T. It was taken with the Bruce three-prism spectrograph, attached to the 40-inch telescope, giving a dispersion of 10 A per millimeter at λ 4500. Messrs. Struve and Hujer were the observers. The lines measured extend through the range of that type of plate—from $H\beta$ to $H\gamma$, and are given in Table I. The intensities therein are purely arbitrary.

A microphotometric tracing was made of this plate, from which the percentages of emission or of absorption in the line contours were reduced. Specimens of some of the iron emission lines, $H\beta$ and $H\gamma$, and the two helium absorption lines λ 4388 and λ 4472 are repro-

[1] *Publications of the Astronomical Observatory, University of Michigan*, **2**, 1, 1916.

[2] *Astrophysical Journal*, **61**, 389, 1925.

[3] *Ibid.*, **65**, 286, 1927.

TABLE I

LIST OF MEASURED LINES, PLATE R-1616, 27 γ CASS

I.A.*	Pos.	INT.†	IDENTIFICATION		
			Atom	Series	Wave-Length
(4340)	. . . .	20	$H\gamma$	. . . .	. . . .
4350.7 E. . . . . 4352.5 E.	Viol. edge Red edge	1	*Fe* II	$b^4P'_2-a^4D'_3$	51.77
4383.1 E. . . . . 4385.5 E.	Viol. edge Red edge	3	*Fe* II	$b^4P'_1-a^4D'_3$	85.26
4387.8 A.	. . . .	. . . .	*He*	. . . .	87.93
4400.0 A.	. . . .	. . . .	. . . .	. . . .	. . . .
4470.0 A.	. . . .	. . . .	*He*	. . . .	71.48
4481.0 A.	. . . .	. . . .	*Mg* II	. . . .	81.33
4488.0 E. . . . . 4489.3 E.	Viol. edge Red edge	2	*Fe* II	$b^4F'_4-a^4F_3$	89.21
4505.5 E. . . . . 4506.9 E.	Viol. edge Red edge	1	*Fe* II	$b^4F'_2-a^4D'_1$	08.29
4514.9 A.	. . . .	. . . .	. . . .	. . . .	. . . .
4520.0 E. . . . . 4522.2 A. . . . . 4523.5 E.	Viol. edge Red edge	3	*Fe* II	$b^4F'_3-a^4D'_1$	22.64
4546.8 E. . . . . 4549.5 A. . . . . 4551.0 E.	Viol. edge . . . . Red edge	4	*Fe* II	$b^4F'_4-a^4D'_3$	49.48
4552.8 E. . . . . 4555.0 E.	Viol. edge Red edge	2	. . . .	. . . .	. . . .
4555.8 E. . . . . 4557.8 E.	Viol. edge Red edge	2	*Fe* II	$b^4F'_4-a^4F_4$	55.90
4575.6 E. . . . . 4577.3 E.	Viol. edge Red edge	1	. . . .	. . . .	. . . .
4582.1 E. . . . . 4583.2 A. . . . . 4585.2 E.	Viol. edge . . . . Red edge	5	*Fe* II	$b^4F'_5-a^4D'_4$	83.84
4600.9 E. . . . . 4602.8 E.	Viol. edge Red edge	2	*Fe* II *N* II	$a^6S'_3-a^4D'_2$ (Too near *N* II)	01.49 . . . .
4627.0 E. . . . . 4629.0 A. . . . . 4630.5 E.	Viol. edge . . . . Red edge	3	*Fe* II	$b^4F'_5-a^4F_5$	29.33

* E = emission; A = absorption.   † Intensities are arbitrary.

TABLE I—*Continued*

I.A.*	Pos.	Int.†	Identification		
			Atom	Series	Wave-Length
4642.0 E..... 4646.0 E.....	Viol. edge Red edge	1	*N* II	....	43.11
4654.0 E..... 4658.0 E.....	Viol. edge Red edge	3	*Fe* II	$a^4S_3-a^4D'_3$	56.98
4666.7 E..... 4669.2 E.....	Viol. edge Red edge	2	*Fe* II	$b^4F'_4-a^4F_5$	46.75
4680.6 E..... 4683.5 E.....	Viol. edge Red edge	1	....	....	....
(4861.)......	....	30	$H\beta$	....	....

duced in Figure 1. The positions in angstroms, as shown in the table, are rather roughly estimated, for purposes of identification, from the comparison spectrum, as measured with the micrometer. From these a scale of wave-lengths was converted and directly ruled on the microphotometric tracing, and the positions of the lines further corroborated and identities established. Owing to unequal shrinkage in the bromide paper, used for the tracing, and to mechanical inaccuracies in the movement of the microphotometer itself, no very strict claim may be held for the wave-lengths thus established. For purposes of comparison the contours of $H\beta$ and $H\gamma$ from one of the usual Eastman 40 plates are also shown (No. R-1362).

It will be noted that the *Fe* lines show similar characteristics to the *H* lines, both as regards the bright components and the central absorption. The emission portions have also a nearly equal displacement in angstroms, assuming values quite consistent with the earlier measures of Curtiss. The *He* absorption lines at λ 4388 and λ 4472 and the *Mg* line at λ 4481 are quite shallow. Mr. Struve, in a late paper,[1] has called attention to the relative intensities of these two *He* lines, finding the greater value for λ 4472. As the figure indicates, the contours bring out the inverse ratio for this star.

Of course no claim can be made for the reality of individual features of these contours. There seems to be a marked discrepancy in the ratios of the percentage of emission of $H\beta$ and $H\gamma$ between

[1] *Nature*, **122**, 994, 1928.

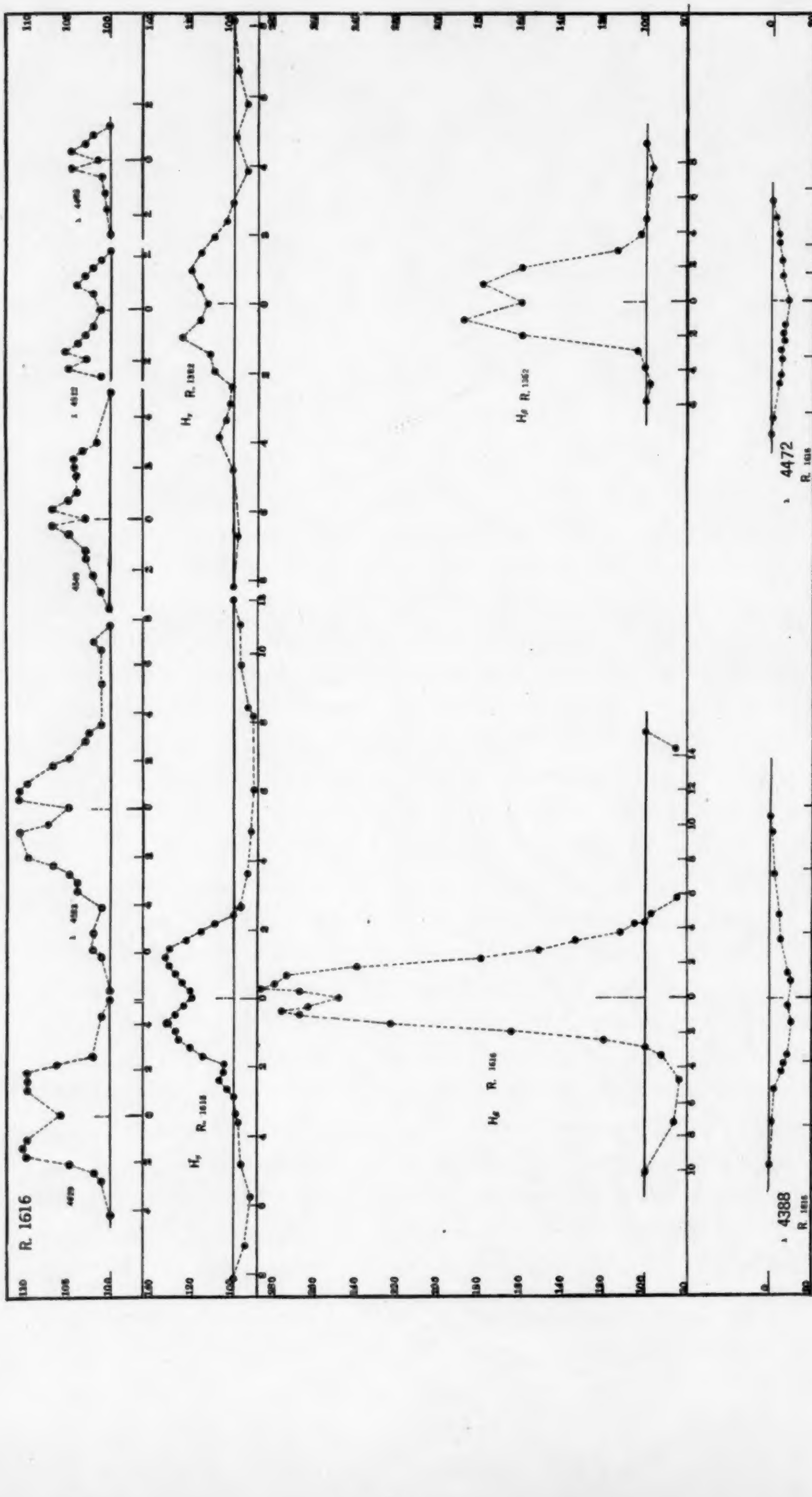

FIG. 1.—Contours of lines in spectrum of 27 γ Cassiopeiae. (Abscissae are given in Angstroms. Ordinates are percentages of emission or absorption measured from continuous spectrum.)

the two plates. It is noticeable that the central absorptions appear proportionately much deeper by visual examination than are indicated by the microphotometric deflections. This is especially apparent in the case of $H\beta$. There is undoubtedly an effect of integration to be reckoned with here. Also it is quite evident that the background fog is greater at this point on this specific plate, whereas the continuous spectrum has fallen away almost entirely. On the other hand, owing to the Eberhard effect, the central absorptions might be expected to be deepened.

There is some evidence for the asymmetry and unilateral intensity, noted by Miss Payne,[1] although it will require a more extended investigation, involving a series of such plates, to establish definitely the reality of these and similar features. The writer hopes that a program of a more quantitative nature in this type of spectra may be carried out during the coming winter.

The kindly proffered aid and suggestions of Dr. Struve and Mr. Elvey, of the Yerkes staff, is gratefully acknowledged.

YERKES OBSERVATORY
November 1929

[1] *Harvard Bulletin*, No. 837, 1926.

NEW DETERMINATION OF THE SPECTROSCOPIC AND VISUAL ORBITS OF 61 μ ORIONIS

By PAUL BOURGEOIS

ABSTRACT

Elements of the orbit of the spectroscopic binary.—New observations obtained this year permit the completion of the set of elements of the spectroscopic binary through a complete period of variation of γ. For 1929.7: $\gamma=+42.1$ km/sec.

Elements of the orbit of the visual binary.—A table is given of ten visual observations of the companion covering the period of time from the discovery in 1914 to 1927. From the velocity-curve of the center of mass of the spectroscopic binary the following elements were deduced: $\gamma=+43.3$ km/sec.; $P=17.5$ years; $e=0.76$; $K=14.9$ km/sec.; $\omega=43°$; $T=1911.75$; $a \sin i=850{,}000{,}000$ km; $(m_1^3 \sin^3 i)/(m+m_1)^2=0.60$. The visual observations give the following additional elements: $i=+70°$; $\Omega=39°$; $a=0\overset{''}{.}27$; $\omega=223°$ and a (spec.) $=900{,}000{,}000$ km; $m_1^3/(m+m_1)^2=0.72$.

A variation of T was found having a period of 17.5 years. The light-equation is not sufficient to explain this variation. Perturbations in the triple system may be responsible for a part of it.

The star 61 μ Orionis ($\alpha_{1925.0}=5^{h}58\overset{m}{.}2$; $\delta_{1925.0}=+9°39'$) has been known as a spectroscopic binary since 1906,[1] and suspected to be a triple system a few years later; it was also discovered to be a visual binary in 1914.[2] Edwin B. Frost and O. Struve in 1924 made a careful study of this star and an attempt to determine the elements of the visual pair.[3] This is of great interest since the visual double star is a very difficult object and many years might elapse before a good determination of the orbit from the visual observations alone could be secured.

The rough elements deduced in 1924 were:

$P=$ 18 years	$e=0.6$
$\gamma=+40.8$ km/sec.	$T=1911.7$
$K=$ 4.0 km/sec.	a $\sin i=300{,}000{,}000$ km
$\omega=$ 98°	

It was also assumed at that time that the orbit could not be much inclined to the line of sight.

Additional information was given by Edwin B. Frost, Storrs B. Barrett, and O. Struve in 1929.[4] The total observed range in the

[1] Edwin B. Frost, *Astrophysical Journal*, **23**, 266, 1906.

[2] *Lick Observatory Bulletin*, **8**, 93, 1914.

[3] *Astrophysical Journal*, **60**, 192, 1924.

[4] *Publications of the Yerkes Observatory*, **7**, Part I, 1929.

value of γ became 29 km/sec., and the other elements seemed not to be much altered. The star was kept on the program of the Yerkes Observatory for continued observations.

As soon as observations of this star could be begun this fall, new plates were taken with a dispersion of three prisms. The results of my measures on these plates are given in Table I, the last column giving the O – C resulting from a new determination of the spectroscopic orbit.

TABLE I

RADIAL VELOCITIES OF 61 μ ORIONIS

U.T.	Observed By	Quality	Vel. in km/sec.	O–C km/sec.
1929 Sept. 15.415....	Hu, S	f	+63.5	+0.3
Sept. 18.399....	Hu, S	f	16.4	+1.9
Sept. 21.424....	σ, Bgs, S	p	44.8	–0.9
Sept. 24.424....	Hu, S	p	65.3	– .8
Oct. 5.424....	σ, S	g	21.0	– .2
Oct. 8.391....	σ, S	p	69.9	.0
1929 Oct. 14.382....	σ, S	g	+19.5	0.0

In Table I the names of the observers are indicated as follows: Bgs = P. Bourgeois; Hu = C. Hujer; σ = O. Struve; S = F. R. Sullivan. In the column for quality of the plate, g = good; f = fair; p = poor.

The general characteristics of this orbit are well known; therefore I assume it to be circular with a period of 4.44746 days.

I obtain the following elements:

$$\gamma = +42.1 \text{ km/sec.} \qquad T = 2{,}423{,}862.224$$
$$P = 4.44746 \text{ days} \qquad a \sin i = 1{,}800{,}000 \text{ km}$$
$$K = 29.0 \text{ km/sec.} \qquad \frac{m_1^3 \sin^3 i}{(m+m_1)^2} = 0.0113$$

The probable error of one observation is ± 0.6 km/sec.

Figure 1 gives the velocity-curve of the spectroscopic binary in 1929.

Table II contains for all the determinations of the circular orbit thus far obtained the epoch, the period, T, K, and γ. In order to obtain a better representation, I have adjusted the values of T for the groups 6, 7, and 8. These values of T were originally given by Edwin B. Frost, Storrs B. Barrett, and O. Struve[1] as being all equal to 2,423,862.174.

[1] *Ibid.*

Table III contains all the visual observations available until now, with the remarks of the observers.

Several trials were necessary in order to secure an orbit that would represent both the visual and spectroscopic data. The following elements are a compromise between the somewhat conflicting observations.

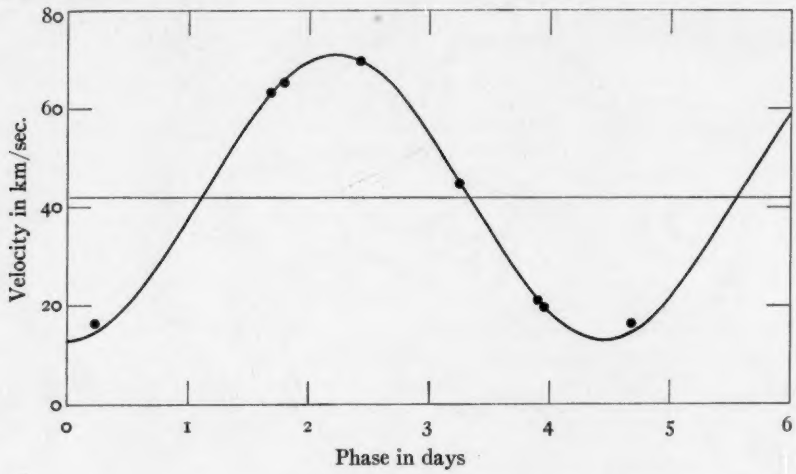

FIG. 1.—Velocity-curve of the spectroscopic binary 61 μ Orionis in 1929

I get for the elements deduced spectroscopically:

Elements		Group	O−C km/sec.
$\gamma=$	$+43.3$ km/sec.	1	-0.5
$P=$	17.5 years	2	(-1.9)
$e=$	0.76	3	$+0.1$
$K=$	14.9 km/sec.	4	$+0.7$
$\omega=$	$43°$	5	$+1.1$
$T=$	1911.75	6	-1.0
$a \sin i=$	850,000,000 km	7	0.0
$\frac{m_1^3 \sin^3 i}{(m+m_1)^2}=$	0.60	8	$+0.1$
$L=$	379*	9	-1.1
$N=$	406*		

* Notation according to *Union Observatory Circular*, No. 68.

The probable error of one epoch is ± 0.5 km/sec.

Figure 2 gives the velocity-curve of the center of mass of the spectroscopic binary. The second group has been omitted as having very little weight according to a remark given with the general table of the early observations.

TABLE II

ELEMENTS OF THE SHORT-PERIOD SPECTROSCOPIC BINARY 61 μ ORIONIS

Group	Epoch	Number of Plates	P in Days	T in J.D.	K in km/sec.	γ in km/sec.
1.......	1906.9	25	4.44746	2,423,862.194	30.4	+44.0
2*......	1908.0	17	4.44746	2,423,862.358	28.8	44.3
3.......	1915.2	36	4.44746	2,423,862.144	30.1	37.3
4.......	1917.5	24	4.44746	2,423,862.141	30.5	39.3
5.......	1921.7	22	4.44746	2,423,862.174	30.8	42.7
6.......	1927.0	9	4.44746	2,423,862.299	32.0	49.0
7.......	1928.0	10	4.44746	2,423,862.326	33.5	55.2
8.......	1928.9	7	4.44746	2,423,862.344	32.	66.
9.......	1929.7	7	4.44746	2,423,862.224	29.0	+42.1

* Group 2 is uncertain; see *Astrophysical Journal*, **60**, 194, 1924.

TABLE III

VISUAL OBSERVATIONS OF 61 μ ORIONIS

Date	Position Angle	O−C	Dist.	O−C	Number of Nights	Observer	Remarks
1914.74..	32°0	− 3°5	0″36	+0″05	3	Aitken	
1917.41..	20.4	− 8.2	.38	.00	2	Aitken	Difficult
1918.11..	16.4	−10.6	.31	− .08	1	Aitken	Very difficult
1919.97..	25.8	+ 3.0	.38	+ .01	1	Van Biesbroeck	
1920.51..	15.8	− 5.7	.32	− .04	2	Aitken	
1921.80..	22.7	+ 4.8	.30	− .03	2	Aitken	Very difficult
1924.24..	18.0	+10.1	.20	− .04	3	Van Biesbroeck	
1924.74..	358.3	− 6.3	.23	+ .02	2	Van Biesbroeck	
1926.94..	350.0	+21.0	.13	+ .03	4	Van den Bos	Elongation extremely doubtful
1927.13..	345.9	+24.0	0.11	+0.02	4		

I get from the visual data the following additional elements:

$$i = +70^\circ \qquad \omega = 223^\circ$$

$$\Omega = 39^\circ \qquad a\ (\text{spec.}) = 900{,}000{,}000\ \text{km}$$

$$a = 0\overset{''}{.}27 \qquad \frac{m_1^3}{(m+m_1)^2} = 0.72$$

The positive sign of the inclination results from the radial velocity, because the star was receding when passing through the ascending

node. The residuals O−C are given in Table III and were computed with the tables of the Union Observatory[1] with the constants:

$A=0.193 \qquad F=-0.101$
$B=0.075 \qquad G=-0.168$

Figure 3 shows the visual observations and the apparent orbit best adjusted to them and to the spectral observations.

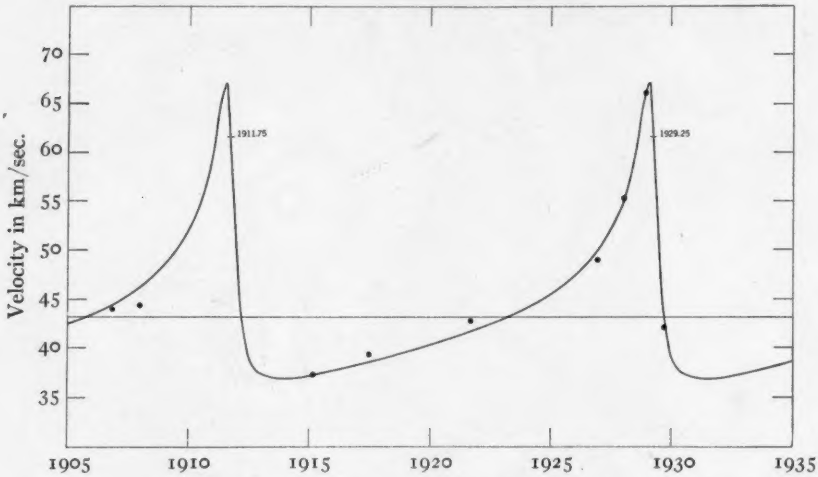

FIG. 2.—Velocity-curve of the center of mass of the spectroscopic binary 61 μ Orionis.

We now refer to the following remark by Edwin B. Frost and O. Struve in their paper of 1924: "If the adopted value of the period is not quite correct, slightly different values of T would result, but in that case all these values, if plotted against the time, would fall on a straight line, which is not the case in fact. The cause is probably to be found in the light equation."[2] Accordingly I plotted the values of T obtained for the several groups, against time. There appears a variation that seems to be periodic and that has the same period as the velocity-curve of center of mass; but the amplitude is too large to be explained by the light-equation alone. This may in part be the result of perturbations in the triple system.

[1] *Union Observatory Circular*, No. 71, Appendix.

[2] *Astrophysical Journal*, **60**, 192, 1924.

The upper curve in Figure 4 illustrates the observed variation. In the lower curve I have shown the theoretical curve due to light-

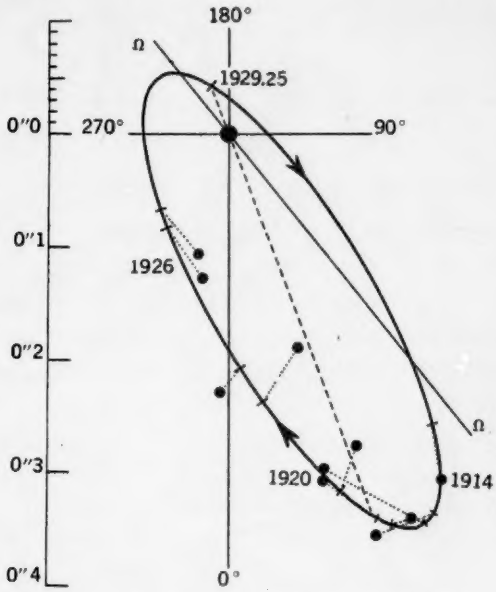

FIG. 3.—Orbit of the visual binary 61 μ Orionis

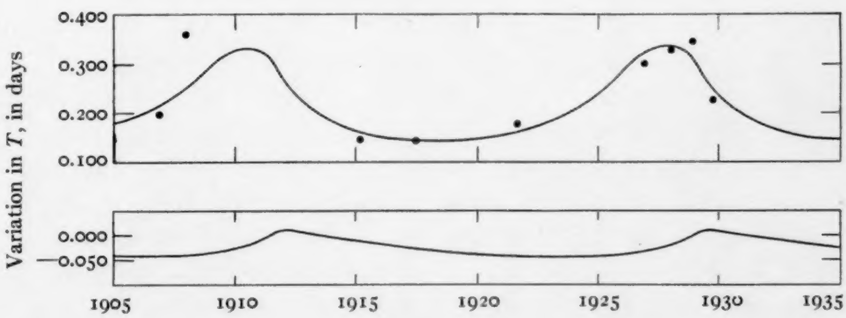

FIG. 4.—Variation of T and light-equation

equation as computed from the elements. In drawing the smooth curve I have avoided the value obtained for the second group for the reason given above.

For the benefit of visual observers I have computed an ephemeris for the coming years:

Date	Position Angle	Distance
1930.0	53°3	0″11
1930.5	44.8	.18
1931.0	40.8	.23
1931.5	38.1	.27
1932.0	35.9	.30
1933.0	32.9	.35
1934.0	30.3	.37
1935.0	27.9	.39
1936.0	25.9	0.39

Through the kindness of Professor Edwin B. Frost I was given an opportunity to use the material available at the Yerkes Observatory for this paper. I beg to acknowledge here my gratitude to the C. R. B. Educational Foundation for assigning to me an advanced fellowship which has made possible my visit to the United States, also to Messrs. Edwin B. Frost, G. Van Biesbroeck, and O. Struve for helpful advice so freely given.

YERKES OBSERVATORY
November 8, 1929

MINOR CONTRIBUTIONS AND NOTES

CONTOURS OF CERTAIN LINES IN 88 γ PEGASI

ABSTRACT

The *contour* of the line at λ 4470 in the star 88 γ Pegasi was found to be ***appreciably broader than*** the contours of several *other lines*, due to Si^{++} and to Mg^{+}. This adds some weight to Struve's *identification* of this line with a *forbidden* line of ***helium***, since the broadening is probably caused by *mol-electric Stark effect*.

We have examined the contours of a certain number of lines in the spectrum of 88 γ Pegasi, taken on a Process plate with the dispersion of three prisms (10 A per millimeter at λ 4500). The observer during this exposure with the Bruce spectrograph was Mr. C. Hujer. The spectrogram was analyzed with the registering microphotometer of the Yerkes Observatory, according to the method adopted by C. T. Elvey. The lines we have examined are: *He* 4388, *He* 4472, Mg^{+} 4481, Si^{++} 4552, Si^{++} 4568, and Si^{++} 4574. The results are given in the figure. The lines of silicon and magnesium are symmetrical and very sharp. The line *He* 4388 seems to be broadened to the violet, in accordance with the results of Elvey.[1] The contour of the violet wing of the line *He* 4472 shows very clearly the existence of the forbidden line *He* 4470 identified as such by O. Struve in recent papers.[2]

By supposing the line *He* 4472 to be symmetrical we obtain the contour of *He* 4470, by subtracting the intensities on the red side of *He* 4472 from the corresponding values on the violet side. This is shown under *e* in the figure. It will be seen that the line at λ 4470 is much broader than any of the lines of Si^{++} or of Mg^{+}. This difference is probably due to the fact that neither Si^{++} nor Mg^{+} are much broadened by Stark effect, while for helium this type of broadening is very pronounced.[3] The identification of the line λ 4470 with forbidden helium is thus made more probable.

[1] *Astrophysical Journal*, **69**, 237, 1929; *ibid.*, **70**, 141, 1929.

[2] *Ibid.*, **69**, 173, 1929; *ibid.*, **70**, 85, 1929.

[3] Struve, *ibid.*, **69**, 178, 1929.

We have supposed that the line *He* 4472 is symmetrical. It is evident that any asymmetry in this line toward the red could only make λ 4470 still broader. The unsymmetrical shape of this latter

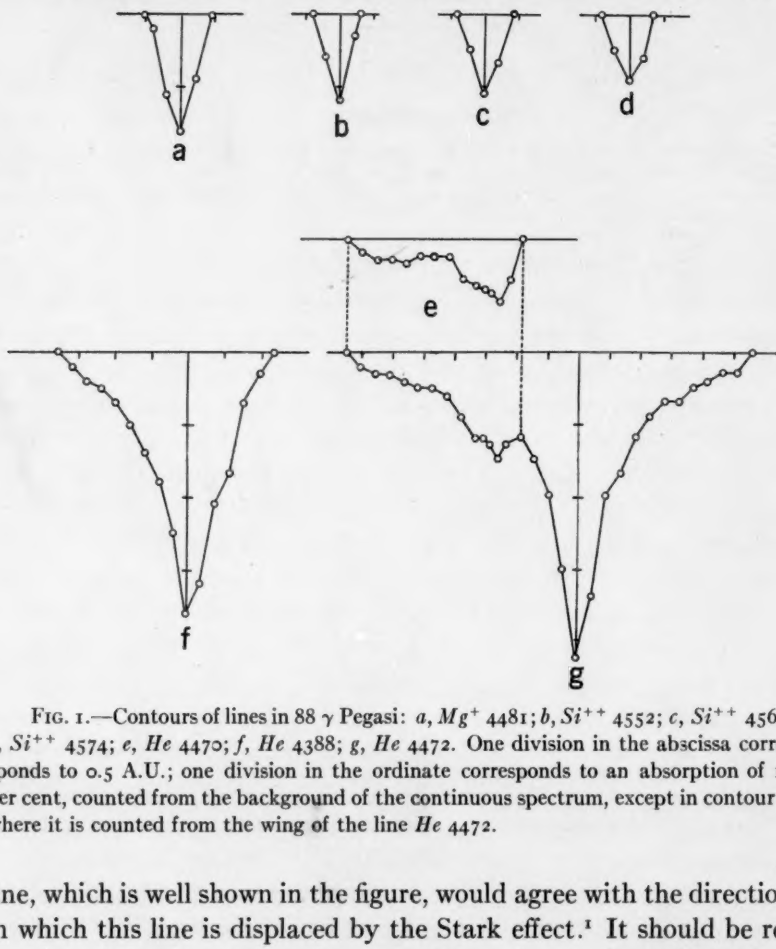

FIG. 1.—Contours of lines in 88 γ Pegasi: *a*, Mg^{+} 4481; *b*, Si^{++} 4552; *c*, Si^{++} 4568; *d*, Si^{++} 4574; *e*, *He* 4470; *f*, *He* 4388; *g*, *He* 4472. One division in the abscissa corresponds to 0.5 A.U.; one division in the ordinate corresponds to an absorption of 10 per cent, counted from the background of the continuous spectrum, except in contour *e*, where it is counted from the wing of the line *He* 4472.

line, which is well shown in the figure, would agree with the direction in which this line is displaced by the Stark effect.[1] It should be remembered, however, that the asymmetry of 4470 depends in part upon the assumption that 4472 is symmetrical.

J. PAUWEN

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[1] *Ibid.*, p. 192, 1929.